R
2/3

H. d. 4. 7 b 25

The Library of the
Wellcome Institute for
the History of Medicine

MEDICAL SOCIETY
OF
LONDON
DEPOSIT

Accession Number

Press Mark

BLACK, J.

LONDON MEDICAL SOCIETY

LECTURES

ON THE

ELEMENTS OF CHEMISTRY,

DELIVERED

IN THE UNIVERSITY OF EDINBURGH;

BY THE LATE

JOSEPH BLACK, M.D.

PROFESSOR OF CHEMISTRY IN THAT UNIVERSITY,

PHYSICIAN TO HIS MAJESTY FOR SCOTLAND; MEMBER OF THE ROYAL SOCIETY OF EDINBURGH, OF THE ROYAL ACADEMY OF SCIENCES AT PARIS, AND THE IMPERIAL ACADEMY OF SCIENCES AT ST. PETERSBURGH.

NOW PUBLISHED FROM HIS MANUSCRIPTS,

BY

JOHN ROBISON, LLD.

PROFESSOR OF NATURAL PHILOSOPHY IN THE UNIVERSITY OF EDINBURGH.

VOL. II.

EDINBURGH:

PRINTED BY MUNDELL AND SON,

FOR LONGMAN AND REES LONDON, AND WILLIAM CREECH EDINBURGH.

1803.

Mag. 4-6

LECTURES

ON

CHEMISTRY.

CHEMICAL HISTORY.

CLASS II.

EARTHS.

THE nature of the ſalts in general, and that of the principal varieties of them, have been already explained to you. It was proper to preſent that claſs of natural ſubſtances to your conſideration the firſt of all, becauſe the ſalts are the moſt active of the objects of chemiſtry. They ſhew an attraction, or a diſſolving and active power, in mixture with a great multitude of other ſubſtances. We cannot therefore deſcribe conveniently the nature of any of the other objects of chemiſtry, without taking in the relation of ſuch objects to the different ſalts, or to ſome of the principal ſpecies of them.

Next after the ſalts, I have found it moſt convenient to deſcribe the earthy bodies; and I have two reaſons for chooſing this arrangement. The firſt is, that ſome of the earths reſemble the ſalts ſo much by their chemical relations, that the tranſition from the one to the other is perfectly eaſy, and the knowledge of the ſalts muſt therefore facili-

tate the apprehenſion of what is to be ſaid of the earths. The ſecond reaſon is, that we muſt have ſome knowledge of the earths, before we can proceed conveniently to the ſtudy of the other objects of chemiſtry which have not yet been conſidered.

That I may prepare you for underſtanding ſome terms and expreſſions, which I ſhall have occaſion to uſe, in ſpeaking of the different ſtates and conditions in which we find the different earthy and ſtony ſubſtances, I am under the neceſſity of ſtating or deſcribing a number of facts or appearances, which, to be clearly apprehended, require a more than uſual exertion of the attention. I truſt, therefore, that you will favour me with your attention, which, at any rate, will be well employed, as, in thus preparing you, I muſt make known to you many of the moſt important and inſtructive phenomena that are connected with the natural hiſtory of this globe.

The common definition of earthy and ſtony ſubſtances is, that they are bodies not ſoluble in water, not inflammable, and whoſe denſity or ſpecific gravity, compared with that of water, does not exceed the proportion of four to one. Theſe characters are choſen to diſtinguiſh them from ſalts, and from ice, by the want of ſolubility in water; from inflammables by the want of inflammability; and from the metallic ſubſtances by inferior weight.

This definition, however, as well as that commonly given of the ſalts, is not unexceptionable. The diſtinction taken from the want of ſolubility may be objected to, as not applicable to ſome of the earths, which are perfectly and totally ſoluble in water. Such is calcareous earth, and barytes, and ſtrontian ſpar. And it muſt be confeſſed, that ſome of theſe earths, or natural ſubſtances, which appear to belong more properly to the claſs of earths than to any other, are truly of an intermediate nature between ſalts and earths, partaking of the properties of each, in ſuch a manner, that it is difficult to ſay which of the two claſſes they reſemble the moſt. Mr. Fourcroy, thinking that they reſemble the ſalts more than the earths, has removed them from

the claſs of earths, and deſcribed them as ſalts. But it is of little importance under what name a thing is deſcribed, provided it be well deſcribed, and the nature of it thoroughly made known.

There is, in every part of nature, a tranſition from one ſet of her productions to another; ſo gradual, that we cannot find a preciſe limit between the claſſes or aſſemblages of them which we chooſe to make.

Beſide thoſe qualities of the earths which are commonly given, to diſtinguiſh them as a claſs from other bodies, they have one which, though not taken into the definition, does, I believe, always make a part of the general idea of an earthy ſubſtance in the mind of a chemiſt. This quality is the great degree of fixedneſs in the fire, by which the earthy and ſtony bodies, in general, excel all the other claſſes of the objects of chemiſtry.

The ſubſtances which belong to this claſs are well known to exceed greatly in quantity all the other objects of our ſcience. They compoſe almoſt the whole of the ſolid materials of this globe which we inhabit. It is, therefore, proper to take ſome notice here of the ſituation and arrangement of the earthy bodies in the interior part of the globe, ſo far at leaſt as we have yet been able to penetrate into it, which we muſt confeſs is only to a very ſmall depth. This ſtep is neceſſary, that we may have an opportunity to explain ſome terms which are in general uſe, in deſcribing the different ſtates and conditions in which the principal ſpecies of earths are found in nature. But my obſervations on this ſubject have a more important aim. The deſcription to be given of the natural ſituation and condition of the earthy ſubſtances, and of thoſe which they incloſe and contain, give the moſt evident marks of a gradual change, both in the ſituations, forms, and even properties, of thoſe ſubſtances. As all theſe are the effects of heat and mixture, operating by means of chemical forces, it is plain that the changes exhibit a ſeries of inſtructive obſervations, and muſt furniſh us with informations which nothing but the length of time, and the enormous preſſures competent to theſe ſituations, could procure. This is a valuable

addition to all the momentary labours of our little laboratories and experiments. And, on the other hand, our chemical knowledge enables us to underſtand many of thoſe changes which muſt otherwiſe have been myſterious and unaccountable. Thus will chemiſtry and natural hiſtory derive mutual aid and improvement.

We have acquired ſome knowledge of the ſtate of the interior parts of the earth, by obſerving the excavations formed accidentally by torrents of water, and by digging deep pits in many different places for the purpoſes of mining, or, on ſome occaſions, for procuring water.

Whenever we have had opportunities, in theſe different ways, for obſerving the conſtruction of the interior parts of the globe, it has been perceived that the matter of which it is compoſed is arranged, for the moſt part, in extenſive beds, layers, or ſtrata, compoſed of different materials, and very various in their thickneſs, but generally parallel to one another, and in which we ſee many parallel diviſions, like the leaves of a book. Where the matter of the earth is arranged in this manner, it is called STRATIFIED MATTER, or STRATA.

This arrangement, however, is perceived in few places only, at the ſurface of the ground. The ſurface is covered almoſt every where, to different depths, with a confuſed rubbiſh and looſe earth, compoſed moſtly of the materials which lie more ſolid and regular below; a part of theſe having mouldered down into this rubbiſh and earth, and, in moſt caſes, having been removed by the action of water to a conſiderable diſtance from the place to which they originally belonged.

Before we can ſee the appearances of the ſtratified matter, we muſt therefore penetrate through this rubbiſh, or find places where it has been broken through, or ſwept away, for a depth of ſome feet or fathoms, or, in many caſes, for a much greater depth; and then we ſeldom fail to perceive them.

The parallel poſition with reſpect to one another, and the great extent and equal thickneſs of theſe ſtrata, have been moſt diſtinctly ſeen

in mining countries, where frequent pits have been dug, to reach the objects of the miner; alſo in digging of wells in populous countries.

Derbyſhire is an example of a mining country, in which a very great number of pits have been dug, on account of numerous metallic veins of lead ore which it contains: And Mr. Whitehurſt has given an account of the general experience and knowledge that has been acquired by the frequent perforations of the earth in that country.

The country around Newcaſtle is another example, where, on account of the abundance and numerous ſtrata of coal which are found there, the interior parts of the earth have been diligently examined by numerous pits, and by other means, as boring, &c.

From the inſight that has been got on all ſuch occaſions, it has appeared that the ſtrata lie in very different poſitions with reſpect to the horizon in different places; that in ſome diſtricts they are level or horizontal; that in others, and theſe the greater number, they decline from the horizontal poſition, or have what is called a DIP; that in others, they are ſomewhat waved, or alternately riſe and ſink in an irregular manner; and in others, are thrown into *diſorder* by interruptions, ſudden bendings, and fractures, and by very ſteep declinations from the plane of the horizon. There are even examples of two ſets of ſtrata in different poſitions, the one over the other; the undermoſt ſet commonly erected, more or leſs, and the hardeſt; the uppermoſt leſs erected, or horizontal, and ſofter. This is ſeen in the banks of the river Jedd, near Jedburgh.

Such are the different ſtates of the ſtratified matter which is found in almoſt every place where we have opportunities to examine the interior parts of the earth.

But I muſt farther remark, that in many places, and eſpecially in thoſe countries in which we find the ſtrata the moſt diſordered, we generally alſo find large quantities of ſtony matter, in which we cannot perceive that ſtratified arrangement of parts, but which conſtitutes enormous maſſes, irregular in their form and ſize, ſometimes ſpread

out or interpoſed between the ſtrata, but never of ſuch an equal thickneſs, or diſpoſed in ſuch a regular manner; and often ſplit into numerous pieces.

The ſtony matter which has this appearance, may be diſtinguiſhed from ſtratified matter by the name of rock, or rocky matter.

An example of the difference between the rocky and the ſtratified matter, is to be ſeen in Saliſbury Craig, which is an extended maſs of rocky matter, with ſtratified matter below it, and above ſome parts of it: And Arthur's Seat is a maſs of rocky matter, but has ſtratified matter under it.

Theſe maſſes of rocky matter, in which we cannot perceive any ſtratified arrangement, compoſe in ſome countries very high mountains. In other places, the ridges, or chains of mountains, are formed more or leſs by ſtratified matter that is uncommonly hard, and the ſtrata of which are much declined from the horizontal poſition; in conſequence of which, their edges project above the general ſurface of the globe, to form thoſe mountainous ridges. Frequently, however, the very high mountains are formed by an intermixture of *rock* with theſe hard and erected ſtrata, which, along with it, have ſuſtained the injuries of time and of the weather, better than the ſofter matter which ſurrounded them; and therefore part of them now remains, and forms thoſe projections, after the ſofter matter has been demoliſhed around, and waſhed away to a great depth.

That the ſurface of the globe has every where undergone great changes in this way, by demolition, and removal of the materials to very great diſtances, will be clearly ſeen by any perſon who ſurveys it with a diſcerning eye. When we aſcend very high mountains, the rocky tops of them are all ſhattered and ruinous, and their ſides are covered in many places to a great depth with the rubbiſh which has fallen from the upper parts of them. In this rubbiſh, we find deep ſcars and ravins, formed in heavy rains and ſtorms, by torrents of water, which, by their repeated effects, gradually waſh down that

rubbiſh into the lower grounds. During the great length of time required for its complete deſcent, it undergoes further demolition and decay, into gravel, ſand, and earth; and, under theſe forms, is at laſt ſpread out by the brooks and rivers, to form the plains and the ſands found on the ſhores of the ſea. For, as the rivers, in conſequence of the unequal reſiſtance of the different ſoils through which they run, have in general a ſerpentine courſe, and are gradually undermining their banks, and ſhifting their channel in different places, they have the natural effect to undermine, and bring to a level, the eminences and accumulations of ſoil and rubbiſh which have been formed in particular places; and, for this reaſon, all great rivers are in general ſurrounded in their courſe toward the ſea with immenſely extenſive plains, which have been formed by themſelves.

Any perſon who wiſhes to be ſatisfied of what I have now ſaid of the demolition that is going on in the elevated parts of the earth's ſurface, muſt viſit very high, mountainous, and Alpine countries, or read the accounts of thoſe who have viſited them. Common mountains and hills do not ſhew it ſo evidently, for although theſe too are ſuffering a gradual demolition and waſte, it is ſo ſlow, on account of their being leſs expoſed to the violence of the elements, that it is not obvious. They become covered with rubbiſh, and ſoil, and vegetables,—all which defend them in ſome meaſure from the leſs violent impreſſion of the ſtorms; while the tops of very high mountains are ſo much expoſed to their fury, that ſoil or rubbiſh cannot remain on them, but is ſwept away as faſt as it is produced. There is a fine example of this in the mountains of Arran, in the weſt, which are among the higheſt in theſe iſlands. The ſummits of thoſe mountains are all ruinous. They preſent, in ſome places, lofty precipices, which terrify the beholder by their awful heights, and by the mountainous blocks of ſtone that are prominent from them, and ſeem ready to fall and to cruſh every thing below them. They are acceſſible only to eagles and other birds of high flight, who chooſe

them for their habitation. The foot of theſe precipices terminates in a ſteep ſlope of great extent, forming a great part of the ſide of the mountain. This ſlope is compoſed entirely of blocks of ſtone and of rubbiſh, which, in the lapſe of time, have fallen from the top of the precipice.

For more examples of ſimilar appearances, I refer you to the deſcription of the higher parts of the Alps of Savoy, as given by Mr. Sauſſure of Geneva, in his account of different excurſions and journeys he made among them, and in ſome of which he was expoſed to great danger. His accuracy in obſerving, and fidelity in relating what he ſaw, may be entirely relied on: And he preſents his reader with a number of the moſt ſublime objects and inſtructive facts in natural hiſtory.

You will alſo find proofs of the decay and demolition of mountains of granite, deſcribed by Mr. Haſſenfratz, in the eleventh volume of the Annales de Chimie. He ſaw them on the road from St. Flour to Montpellier; and it is a very ſtriking phenomenon.

But I have wandered I may ſay into a digreſſion. I was led into it by endeavouring to illuſtrate the remark I made on the nature of many mountains and chains of mountains; that they are compoſed of hard ſtratified or rocky matter, or of a mixture of both, which now is eminent above the ſurface of the globe around them, in conſequence of the gradual demolition, and removal to a great diſtance, of the ſofter matter which formerly ſurrounded theſe harder materials, which are even themſelves liable to a more ſlow demolition and waſte.

To proceed,—It is neceſſary further to be underſtood, that both the ſtratified and rocky matter are found ſplit or divided, in innumerable places, by fiſſures nearly perpendicular, or acroſs the ſtrata; and that the parts thus broken aſunder are often conſiderably diſplaced with reſpect to one another: The materials on the one ſide of the fracture being frequently ſunk below the level of thoſe on the other, or removed to ſome diſtance from them, ſo as to produce in the ſtra-

tified matter *diſcontinuities* of various wideneſs. Theſe rents and intervals of the fractured ſtrata, or rock, are in general filled with a matter different from that of the rock or ſtratum in which the rents are found. And rents of a certain wideneſs, thus filled up with extraneous matter, are called *veins*, or in Cornwall *lodes*. Theſe veins are ſubject to all the variations of wideneſs, and irregularity of direction, which you can eaſily imagine in fractures and rents of hard ſtrata and rock; and they go down to a depth far below any to which we can reach. The matter which fills them is generally a whitiſh ſtony matter named *ſpar*. It is more pure and more ſimple in its compoſition than moſt other ſtones, but there are ſeveral kinds of it; and intermixed with it, we often find alſo different metallic and mineral ſubſtances. It is indeed in thoſe veins chiefly that the ores of metals are found.

And wherever there are vacuities left in the vein, by its being imperfectly filled, there we are ſure to meet with cryſtallized matter of the ſeveral ſtony and mineral ſubſtances which the vein contains.

In a great many examples, however, the rents and diſcontinuities I have deſcribed, are of greater wideneſs than what are commonly called veins. The wideneſs of veins is from an inch, or a fraction of an inch, to ſeveral feet, or even yards in ſome caſes. But we have examples of rents, the wideneſs of which is equal to many fathoms; and in this caſe, rock or rubbiſh, or other extraneous matter, fills up the interval. When this occurs, the interval and materials which it contains is not called a vein; our miners give it the name of a *dyke*, or *partition*. The extent to which theſe dykes, as well as the veins, are continued downwards into the bowels of the earth, is hitherto unknown. Their depth is plainly much greater than what human art and labour can reach.

Theſe rents and diſlocations of the ſtrata, with the intervals thus formed, and great quantities of rock or rubbiſh which ſometimes fill up theſe intervals, are well known to our colliers, who meet with

them often in cutting out the coal; and they call them in general *troubles;* becauſe there they meet with an interruption in the coal, in conſequence of a diviſion and ſhift of the ſtrata, which they call a *hitch.* The coal is continued beyond this break or hitch, but upon a different level, which the miners muſt find out, ſometimes at great expence. And often they find interpoſed, between the edges of the interrupted ſtrata, a thick partition of rocky or other matter, called a *dyke.*

You will ſee numerous examples of ſmall veins in Saliſbury rock; and examples of ſmall dykes in the bed of Leith water or river; between Canon-mills and the mills above them.

I have only one general fact more to relate, which belongs to this ſubject: It is the diſcovery of ſea-ſhells, corals, and coraline bodies; and of the bones and ſkeletons of fiſh, and other relics of marine productions, which are found in moſt places intermixed with the ſtratified matter. Theſe have appeared on innumerable occaſions, and in all parts of the world, in which ſtratified matter, eſpecially ſome kinds of it, have been examined;—on the ſides of the higheſt mountains, as well as at the greateſt depths to which we have gone in digging the earth. Sea-ſhells have been found at Amſterdam 100 feet deep, or under the ſurface; at Marly-la-Ville, ſix leagues from Paris, at 75 feet deep: Sometimes in mines under a cover of 50, 100, 200, 1000 feet; as in the Alps and Pyrenees. They have alſo been found in mountainous countries at a very great height above the level of the ſea; as in the mountains of Spain, the Pyrenees, the mountains of France and of England, the marble quarries of Flanders, the mountains of Gueldres, and in the heights round Paris; alſo in the Alps, particularly Mount Cenis: And M. Sauſſure, in his inſtructive journeys among the Alps, deſcribes oyſter-ſhells which he found in a part of the Alps to the ſouth-eaſt of Geneva, at the height of 1172 fathoms above the ſea; that is, 7032 feet. *(Sauſſure Voyages dans les Alpes,* p. 393.) They have been ſeen alſo in the Appenines, and in moſt of the ſtone nd marble quarries of Italy. *(Vide Buffon, tom.* 1. p. 408.)

We have evidence alſo of their having been found in the higheſt mountains of the world, the Andes of South America. Don Antonio de Ulloa found petrified ſhells upon the *Cordeliers des Andes dans le gouvernment de Wanca-Vellica*, in 13 or 14 degrees ſouth latitude. Theſe ſhells were found at ſuch a height, that the barometer ſtood there at 17 inches $1\frac{1}{4}$ line French meaſure; that is, at $2200\frac{1}{3}$ fathoms above the level of the ſea, or 13,202 feet. (*Mem. de l' Acad.* 1771.)

And, in all theſe different examples, it is in the ſtratified matter only that they are found.

We alſo find frequently, in ſome kinds of ſtratified matter, impreſſions of the leaves and other parts of vegetables, and pieces of wood, penetrated with ſtony matter of different kinds.

From the whole of theſe phenomena, it is evident that the materials of this globe have been affected, in many places, with violent concuſſions and derangement, and have alſo undergone very great changes in their poſition with reſpect to one another: That what was once covered by the ſea is now land or mountains, and what was once at the ſurface, or covered only with water, is now under cover of ſolid matter to very great depths; and that theſe changes of ſituation have even been often repeated; although the ſucceſſions of the one to the other muſt certainly have been extremely ſlow, and muſt have required a length of time, the limits of which cannot be aſſigned from the phenomena themſelves.

Such are therefore, in general, the appearances which preſent themſelves, when we examine the ſtate of the ſolid materials of which this globe is compoſed, and which moſtly belong to the claſs of earths, which we are now to conſider. Various conjectures and hypotheſes have occurred to the human imagination, to account for the manner in which all this has happened.

To give a ſhort account of the attempts to explain theſe phenomena, I ſhall firſt remark, that all theſe attempts agree in ſuppoſing the materials of the ſtrata to have been arranged by water, depoſiting or

arranging them one over the other, in ſucceſſion. This is inferred not only from their general appearance, ſimilar to that we perceive in lakes, pools, and other ſmall collections of water; at the bottom of which, when they dry up, we find the ſand, mud, and other matters depoſited, or arranged in parallel layers; but alſo from the appearance of ſhells and other marine productions, which abound in the compoſition of a great number of ſtrata. Theſe ſhells are in many places found ſo entire, that they are perfectly well known. The different ſpecies of them are very numerous, and in ſome places they are collected together in immenſe quantities; in quantities ſo great, that we cannot ſuppoſe any other origin for them, but that the place where they lie was once the bottom of the ſea. The ſtrata are ſuppoſed to have been originally in an horizontal, or nearly horizontal poſition. The ſlope or declination from the horizon, which many of them now have, and the apparent diſorder in other reſpects, by rents, changes of level, and interruptions, have been imputed to different cauſes by different theoriſts. Some have imagined that a general convulſion muſt have ſhaken the whole of the globe: Others have ſuppoſed that partial ones have gradually affected the different parts of its ſurface in ſucceſſion.

The general convulſions which have been ſuppoſed ſufficient to produce theſe great effects are, firſt, the cataſtrophe of the deluge, deſcribed in the ſcripture, and by the poets: And Dr. Burnet, in his Theory of the Earth, by giving full liberty to his imagination, has ſhewn ſome ingenuity in the contrivance, I may ſay, of a deluge equal to theſe effects.

The great Dr. Halley, whoſe mind was more occupied with celeſtial objects than with any other, propoſed a ſuppoſition, that this globe had perhaps more than once received a ſhock from a comet, which, impinging on it obliquely, gave it its diurnal rotation; and, by the ſudden communication of ſuch a violent motion, ſhattered and deranged all the materials of it that were near its ſurface.

But the greater number of philoſophers appear now inclined to believe that the convulſions which have deranged the ſtrata have been partial or local only, but with ſuch a ſucceſſion as gradually to affect every part, or almoſt every part of the earth's ſurface; and that they have been produced by ſubterranean fires.

That volcanic and ſubterranean fires muſt have been a very common cauſe of the inequalities of the earth's ſurface, and diſorder of its materials, is plain from the natural hiſtory of this globe. We know that in ſome caſes they have produced ſudden and violent elevations of ſome parts of it, and as ſudden ſinkings and depreſſions of others. We know that ſome of the higheſt mountains are compoſed chiefly of materials thrown out of the craters of volcanoes, and that the moſt convincing proofs are viſible, in innumerable places, of formerly exiſting volcanoes, and craters, the eruptions of which have ceaſed long ſince, while others have ſucceeded to them, and are at preſent in different ſtates of activity.

We know farther, that the action of thoſe ſubterranean fires is not confined to the derangement of the dry land. The agitations which they produce are in many caſes felt with great violence even at ſea; and they are ſo very extenſive, that it is plain they muſt act at an immenſe depth below the ſurface; and therefore far below the bottom of the ocean: A conſequence of which is, that they elevate that bottom in many places ſo as to make it riſe above the ſurface of the waters, where it remains in that elevated ſtate. A great number of iſlands in different parts of the globe ſhew the moſt undeniable proofs that they have had this origin. Such are the iſlands of the Archipelago in the Mediterranean; the Azores, Teneriffe; the iſlands of the Weſt Indies. In all theſe we find lavas, and other ſigns of the action of ſubterranean fire; and in ſome of them ſprings of hot water, and ſulphureous vapours, breaking out at the ſurface, ſhew that the internal fires, although ſmothered, are not completely extinguiſhed.

We find the ſame ſymptoms of internal fire in almoſt all the great

ridges of mountains in the world; and many of the greateſt and moſt active volcanoes are found in thoſe ridges. Such are the Appenines in Italy; the mountains of Sicily; thoſe of France in Auvergne and Dauphigny; the Pyrenean ridge between France and Spain; the immenſe ridge of South America named the Andes, or Cordilleras; the Ruſſian peninſula of Kamtchatka; the mountains of Iceland. In all theſe we find either exiſting volcanoes, or indubitable proofs of their former exiſtence in places where their fires and vapours are not now ſeen. Even in thiscountry, there are ſome ſigns of the former action of ſubterranean fire. Many gentlemen who have viſited volcanic regions, and who have given particular attention to the effects and productions of ſubterranean fire, find ſo much reſemblance between our whinſtone and ſome of the lavas of exiſting volcanoes, that they are perſuaded our whinſtone has been a ſort of lava. And, even ſetting aſide that reſemblance, there are many other reaſons for believing that our whinſtone has been a matter melted by ſubterranean heat *. This, however, does not infer actual volcanoes.

Subterranean fires, therefore, and the internal convulſions, the eruptions and exploſions which they have produced, have evidently ſhaken and deranged the materials of the globe in ſuch a very great number of the parts of its ſurface, that there is very great reaſon to think all the derangement we find in other places has been produced in this way; and this is now the moſt general opinion.

The author, however, who has been the moſt celebrated for his attempt to give a natural hiſtory of the globe, I mean the late M.

* In digging the cellars and common ſewers of the New Town of Edinburgh, freeſtone ſtrata are found to commence a few feet under the ſurface, and occupy the whole ridge on which the buildings are erected. A fiſſure, or rent was found croſſing all theſe ſtrata, to an unknown depth. This fiſſure is completely filled with whinſtone; and in ſome places, the whinſtone ſpreads out a little above, on each ſide of the fiſſure, in the ſame manner as mortar will ſpread out over the joint between two bricks when they are preſſed together. It appears to have been in a fluid, or at leaſt muddy ſtate, and to have been forced through from below.

EDITOR.

Buffon, formed for himſelf a different ſyſtem, which is the moſt fully diſplayed in his *Epoques de la Nature*, and in his *Hiſtoire Naturelle*. He admits that conſiderable changes have been produced by ſubterranean fires; but is of opinion that the principal phenomena are to be accounted for in another way.

He undertook by his ſyſtem to point out the very origin of this globe, as well as that of the other planets which revolve along with it around the ſun. In his opinion, there was a time when the ſun ſtood alone, without any planet, and was viſited only now and then by the comets. One of theſe, coming too near, was drawn, by the attraction of gravitation, into the body of the ſun, and falling obliquely, and with immenſe velocity, againſt his ſurface, daſhed off great maſſes of the melted and burning matter, of which Mr. Buffon ſuppoſed the external parts of the ſun are compoſed. Theſe maſſes were thrown off with different velocities, and flew to different diſtances, before the progreſſive motion was overcome by the attraction of the ſun. At laſt, however, the velocities which theſe maſſes had received were ſo much diminiſhed by this attraction, that it became an equal antagoniſt to them; and theſe maſſes thus became planets, and revolved in the orbits in which they ſtill continue to move.

The ſame powerful impulſe by which they were driven off from the ſurface of the ſun, gave each of them alſo a rotatory motion round its own centre or axis; and being at firſt liquid or melted matter, the attraction of their parts for one another gave them a ſpheroidal form, which, at the ſame time, became a little oblate, by the greater centrifugal tendency from their own centre of ſome parts of them than of others, in conſequence of the rotatory motion they had acquired.

Mr. Buffon further ſuppoſed that, in flying off from the ſun, they carried with them a part of his atmoſphere, which he imagined to be loaded with a vaſt quantity of vapours, produced from every ſort of

matter which can be converted into vapour by intenſe heat, but eſpecially a very great quantity of watery vapours.

The planets continued for ſome time to revolve round the ſun, each of them ſurrounded with its vaporous atmoſphere; for their heat at firſt was too great to admit of any condenſation of theſe vapours on their ſurface. But they cooled by degrees, and the firſt effect of this cooling was, that the external parts of them became ſolid or congealed. The ſolid ſurface, which was formed in this manner, he ſuppoſed to have had all the roughneſs and inequality which is commonly ſeen on the ſurface of earthy, ſtony, and mineral ſubſtances, which have been all melted together and congealed. There were eminences in ſome places, and depreſſions in others; the matter in ſome parts of it was cavernous, and ſpongy and more ſolid in others; and, by the contraction of the cooling matter, a multitude of rents, and chaſms, and vaſt caverns were formed.

Such, he ſuppoſes, was the ſurface of our globe before the water deſcended from the atmoſphere. This did not happen until the heat was ſo much abated, that the vapours, which were contained in ſuch great quantity in the atmoſphere, began to condenſe there, and to fall in rain. His lively imagination paints here a dreadful ſcene, by preſenting the immenſe quantity and violence of thoſe original rains which were deſtined to fill the whole bed of the ocean. They were attended alſo with violent exploſions, and other effects which the water produced when it penetrated into the crevices and caverns of the new earth, the heat of which was ſtill ſo great as to convert very quickly into vapours again the water which firſt fell on its ſurface.

This period of violence and convulſion at the ſurface of the earth, and in the atmoſphere, had a certain duration; but the heat continuing conſtantly to decreaſe, the watery vapours were at laſt more completely condenſed, and the fluid element gained poſſeſſion of the ſurface, and lodged itſelf in the depreſſions and cavities which had been

formed either originally, during the change of the globe from a fluid to a ſolid ſtate, or afterwards, in conſequence of the convulſions I have juſt now mentioned. Still, however, the waters on the ſurface of the globe were for a long time exceſſively hot, and in ſome places even boiling. This was neceſſarily attended with great evaporation, exceſſive rains, and violent commotions of the atmoſphere. And during this period, and the one which immediately preceded it, a great part of the ſolid and hard materials, at the ſurface of the earth, were penetrated by the hot water and vapours, and by more active ſubſtances, which had condenſed along with the water; and thus theſe hard materials were mouldered down into rubbiſh and mud, which formed the firſt ſoil on which vegetables and animals were to be nouriſhed.

Thus Mr. Buffon thought he had accounted for many of the appearances which are obſervable in examining this globe.

In order to explain the reſt, and, particularly, the formation of the ſtrata, and the abundance of ſhells and other relics of marine productions which abound in the compoſitions of many of them, he ſuppoſed that it afterwards underwent more ſlow and gradual changes.

His opinion was, that the ſea is making a conſtant, but very ſlow progreſs, over the ſurface of the globe from the eaſt to the weſt: That this is the conſequence of the action of the trade-winds, and of the general direction of the tides in the ocean, which is from eaſt to weſt. While the trade-winds bruſh the ſurface of the ſea, they affect the water, and in fact produce a current weſtward in the Atlantic, which, by its inceſſant action on the coaſt of America, has formed, as Mr. Buffon ſuppoſed, the great Gulf of Mexico. The water, which in conſequence of this, would be accumulated there, had it not found an outlet, is well known to turn back again in a north-eaſterly direction, and to run in that direction along the coaſt of North America, where it forms what is called the gulph ſtream, which is diſtinguiſhed by its being warmer than the reſt of the ocean in that latitude. A current

weſtward, ſimilar to that I juſt now deſcribed, is known to exiſt alſo in the Pacific Ocean, and in a part of the Indian Ocean, except where it meets with the coaſt and mountains of Africa, which reverberate it, and give it a turn the other way. By this continual impreſſion of the ſea on the eaſtern coaſts of the continents and iſlands, Mr. Buffon imagined that the ſhores are worn away; the ſea encroaches on them, and by degrees takes poſſeſſion of their place; the materials of them being depoſited at the bottom, either in a horizontal poſition, or formed by the currents and tides into riſings and depreſſions, or long ſubmarine ridges and extenſive valleys, (if they may be ſo called). And thus he imagined the whole face of the globe has been modelled ſome time or other by the action of the water, and retains every where the relics of the productions of the ſea, from which it received its form.

This ſplendid ſyſtem has in ſome parts of it an air of ſublimity and grandeur, eſpecially as it is embelliſhed by the eloquence of Mr. Buffon. But it certainly ſhews a degree of preſumption and temerity in the author of it, which excite in the mind very different emotions from thoſe that ariſe when the phenomena of nature are explained in a ſatisfactory manner, and with ſtrict attention to principles of reaſoning that are well founded and juſt.

The very firſt ſuppoſition in this grand ſyſtem is totally inadmiſſible,—I mean the ſuppoſition that the planets received the projectile motion by means of which they revolve in their orbits, in conſequence of their being daſhed off from the ſurface of the ſun. According to this ſuppoſition, they could have made no more than one very eccentric revolution. As ſoon as by the conſtant action of gravitation, they were made to bend their courſe again towards the ſun, they could not do otherwiſe than to complete the ellipſe, the one half of which they had deſcribed in flying off to their greateſt diſtance; and in completing this elliptic orbit, they muſt neceſſarily have fallen again into the ſurface of the ſun.

Nor is the other part of his ſyſtem, by which he endeavours to ac-

count for the relics of ſea-productions, which occur in every part of the globe, at all ſatisfactory. We cannot underſtand by it how the ſea ſhould have carried thoſe relics to ſuch a very great height above its preſent level, as 10,000 feet or more. And had the diſtribution of land and ſea depended on this principle, there would have been no land under the line: All the land there would have been worn away and depoſited.

Other attempts have been made more lately to explain this ſubject, ſuch as Mr. Whitehurſt's, in his *Inquiry into the Original State and Formation of the Earth.* Another by Mr. De Luc, of Geneva, in his *Letters to the Queen.* But I cannot enter into all theſe ſyſtems: it would take up too much of our time. They are all conjectures, and liable to great objections.

A ſyſtem has lately been communicated to the public in this country, by Dr. James Hutton, which appears to me much more comprehenſive and ſatisfactory than thoſe. But I think I have done enough when I have prepared you for underſtanding and judging of ſuch attempts, by deſcribing the general facts or appearances to which they refer: While, at the ſame time, I had an opportunity of explaining ſome terms which I ſhall have occaſion to uſe, in mentioning the different ſtates and conditions under which the principal ſpecies of earths are found in nature.

And being thus prepared for a ſurvey of the variety that occurs among the earthy and ſtony ſubſtances, we ſhall next proceed to the examination of them.

When we begin to do this, however, we find the variety of them to be ſo immenſely great, that to give a full account of every particular would take up a great deal too much of your time; and would be otherwiſe improper here, as being the province of a ſeparate inſtitution,—NATURAL HISTORY. I ſhall not therefore attempt a particular deſcription of all the varieties of earthy bodies, but refer you to the authors who have publiſhed ſyſtems on this branch of knowledge.

The moſt eminent are, Wallerius, Cronſtedt, and the late celebrated Profeſſor Bergmann, who made great improvements in our knowledge of many earthy and ſtony ſubſtances, by his accurate and ſkilful analyſis of them. His work on foſſils is tranſlated into our language by Dr. Withering. Mr. Kirwan of Dublin has alſo publiſhed a mineralogy, or ſyſtematic arrangement and deſcription of foſſils, in which he takes advantage of the lights which have been thrown on this ſubject by Bergmann and others; and has added much from his own experiments, ſo as to give in his book the moſt complete enumeration and deſcription of foſſils that has yet appeared.

Theſe authors, and my colleague, the Profeſſor of Natural Hiſtory, will give you information of all the particulars. In this courſe we have not time to follow the ſubject ſo far, but muſt confine our attention to the moſt remarkable and diſtinguiſhed chemical varieties which occur in nature.

Theſe, I think, may be referred to five orders; the denominations and characters of which I ſhall now give you:

The *firſt* of theſe I ſhall call the order of the ALKALINE EARTHS: They have been commonly called ABSORBENT EARTHS. The ſtate in which theſe are found in nature, and that under which they are commonly called abſorbent earths, is not a ſtate of purity, but of combination with a particular ſubſtance with which I ſhall ſoon make you acquainted. But as there is hardly any example of their being found in a pure ſtate, and as the ſtate juſt now mentioned is the ſtate of them to which we are moſt familiariſed, I ſhall conſider and deſcribe them, firſt, as appearing in this ſtate, and afterwards ſhew how we render them pure, and what properties they have in their pure ſtate.

The characteriſtic of them in their natural ſtate is to effervеſce with acids. They appear under many different modes of concretion; from that of looſe earth to the hardneſs of ſtone, but are never ſo hard as to ſcratch glaſs, or give fire with ſteel. On the contrary, a knife can be made to ſcratch them, or make an impreſſion on them.

The *ſecond* order I call the PLASTIC EARTHS. They are commonly called the ARGILLACEOUS, or CLAYEY.

Theſe, when mixed and kneaded with a moderate quantity of water, become a tough and ductile paſte, which is eaſily modelled into any form, and which, if it be afterwards well dried, and then burned with a ſtrong fire, contracts in its dimenſions, and becomes compact and hard.

The *third* order I call the HARD earths or ſtones. They are commonly called the SILICEOUS, or FLINTY.

They are, in general, ſtony maſſes of a larger or ſmaller ſize, the moſt eminent quality of which is hardneſs. Their hardneſs is ſuch that they ſcratch or cut glaſs, and give fire with ſteel; and when a knife or file is applied to them, it does not make the leaſt impreſſion. It is alſo a general quality of them to reſiſt the moſt violent heat of common fires and furnaces without being melted.

The *fourth* order I name the FUSIBLE.

Theſe are commonly ſtony concretions which have conſiderable hardneſs. Some are ſo hard as to ſcratch glaſs, and give fire with ſteel; but they are not quite ſo hard as the hard ſtones. Their moſt remarkable quality is *fuſibility*, or a diſpoſition to be melted in a ſtrong fire.

The *fifth* order I name the FLEXIBLE.

They are concretions of a ſcaly, a plated, or a fibrous ſtructure, eaſily diviſible into parts which are *flexible*, and often *elaſtic*. They are ſo ſoft as to be eaſily ſcraped with a knife; and do not ſuffer much change of their appearance and qualities when expoſed to a moderately red heat.

We ſhall now, therefore, proceed to deſcribe the earthy and ſtony bodies which come under theſe ſeveral diviſions, and begin with the firſt, the alkaline earths, or, as they are commonly called, the abſorbent.

GENUS I.

ALKALINE EARTHS.

OF the alkaline earths and ſtones there are ſeveral kinds, which, in their natural ſtate, are mild inſipid ſubſtances: And it is difficult to perceive in them, by experiments, any ſenſible degree of ſolubility in water.

Their characteriſtic in that ſtate is, that they efferveſce with acids, and are diſſolved by thoſe ſalts; and ſuch is their nature with regard to acids, that they produce ſimilar effects in mixture with them to what the alkalis produce: Upon which account I call them ALKALINE EARTHS. Thus, we find that in general they unite with acids in one certain proportion only. If there is too much of the earth, it is not all diſſolved; if too little, it is united with a part of the acid only, the reſt of the acid remaining free. There is, therefore, the ſame mutual ſaturation here as with alkaline ſalts. The compound produced is likewiſe analogous to a neutral or compound ſalt, and in moſt caſes diſſolves eaſily in water. The acid is rendered leſs volatile by its coheſion with the earth; its acrimony is greatly diminiſhed, and its acid taſte is not perceivable. And further, theſe earths attract different acids with different degrees of force, and this in much the ſame order as that in which they are attracted by alkalis: So that a compound earthy ſalt, which contains the nitric acid, can be decom-

poſed by the vitriolic acid; and one which contains the muriatic acid, by vitriolic acid or nitric acid; and one that contains the acetous acid, by any foſſil acid, &c.

They, therefore, reſemble the alkalis, both in their attraction for acids, and by many particulars in the nature or manner of this attraction: But, on the whole, its force is leſs than that of the alkalis. Moſt compounds of acids with the alkaline earths may be decompoſed by the alkalis, and eſpecially by the fixed alkalis. Theſe unite themſelves to the acid with more force, and cauſe the earths to ſeparate and fall down in the form of white powder.

Such is the general nature of theſe earths: Let us now attend to the different kinds of them.

SPECIES I.—CALCAREOUS EARTHS.

The principal ſpecies, which occurs the moſt abundantly in nature, and is at the ſame time the moſt uſeful, is called the CALCAREOUS EARTH. It is diſtinguiſhed from other alkaline earths by the effects of a moderately ſtrong heat, which changes it into common QUICKLIME.

It is found in a variety of forms or conditions,

1*mo*, Very numerous and extenſive ſtrata are compoſed entirely, or principally, of this kind of earth. Such are the MARBLES, LIMESTONE, and CHALK, which differ from one another only by the degree of purity in which they contain this earth, or by the manner in which it is concreted together. Both chalk and marble are often burnt to make lime, and afford excellent lime. Marbles and limeſtones are found in all parts of the world; and form numerous and extenſive ſtrata,—and ſo does chalk, in ſome countries.

2*do*, This earth is often found in veins, or filling up rents and crevices in rocky mountains, and hard ſtrata. In this ſtate, this

earth is called SPAR, SPATHUM, or, more particularly, CALCAREOUS SPAR, to diſtinguiſh it from ſome other ſtony ſubſtances called ſpars, on account of a reſemblance of form, and of their native ſituation, but which are of a different nature. Its appearance in this ſtate is that of a whitiſh ſtone, more or leſs tranſparent, and which, when broken in pieces by the ſtrokes of a hammer, is ſhivered into fragments of a rhomboidal figure. In ſome veins it is perfectly tranſparent, and is then called ICELAND CRYSTAL. This has caught the attention of opticians, in conſequence of its refracting light in a particular manner, ſo as to make objects appear double. In veins that contain calcareous ſpar, wherever a vacuity remains not filled, the inner ſurface is beſet with cryſtals of the ſame matter, which are columnar or pyramidal; and ſometimes compoſed of two pyramids joined together, and forming one cryſtal.

3tio, It is commonly this earth which forms the ſtony maſſes called STALACTITES. Theſe are ſtony concretions, formed chiefly in the roofs of ſubterranean caves, and cavities of ſome extent. They are produced by waters which contain a ſmall quantity of this earth diſſolved in them, and which, penetrating into ſuch caves, drip from their roofs, or ooze out from their ſides and floors, and depoſit this earth. While it ſeparates ſlowly from the water, it concretes, and forms gradually large pendulous cones and columns, and a variety of fantaſtic figures, which are found hanging from the roofs, or projecting from the ſides and floors of ſuch caverns, and ſomewhat reſemble the icicles more quickly formed from dropping water in froſty weather. The famous cave at the Peak, in Derbyſhire, is a well known example of this. There are ſimilar examples near Slains Caſtle, north of Aberdeen, and in many other parts of the world.

The waters which produce this effect are called PETRIFYING WATERS, on account of their forming theſe ſtony concretions, and ſometimes penetrating and encruſting vegetable and animal ſubſtan-

ces with the ſame ſtony matter, ſo as to convert them, as it were, into ſtone. Such is the ſpring called the Dropping-well, at Knareſburgh in Yorkſhire, which has formed a ſort of quarry of ſtone, by petrifying the moſs and other vegetables which its water paſſes over. There is a ſimilar ſpring in the Duke of Hamilton's deer park, and at Matlock in Derbyſhire.

Waters of this kind are very common in Italy, in conſequence of the great quantities of limeſtones and marbles with which that country abounds. There is a marſh not far from Rome, the water of which incruſts the reeds which grow in it; and by means of theſe waters they have made very pretty medallions.

The formation of theſe calcareous petrifactions and ſtalactites, ſhews plainly that this earth is in ſome degree ſoluble in water; and we have many other proofs of this fact. Calcareous ſtalactites and incruſtations, and the petrifying waters which produce them, are in general found in countries which abound with limeſtone or marble, or other forms of the calcareous earth. Wherever any parts of the calcareous ſtrata are expoſed to the rain, they ſhew moſt evident ſigns of their being ſubject to a ſlow diſſolution and waſte. (A calcareous maſs at Lord Elgin's quarry is diſſolved at top, and incruſted at the bottom). And when more water gains admittance into rents and chaſms of ſuch ſtrata, it gradually enlarges the paſſages through which it runs, and forms at laſt extenſive caverns, in which it is common to find abundance of ſtalactites. The quantity of this earth, however, which pure water can diſſolve, is exceedingly ſmall, as I learned by experiment. But water ſometimes contains other things combined with it, which increaſe its power as a ſolvent of this earth.

4*to*, The ſtony ſhells of all cruſtaceous animals, among fiſh and reptiles, from the coarſeſt to the pearl, are made up of this earth, and a ſmall quantity of animal glue. And of the ſame materials are egg-ſhells formed, as alſo thoſe marine bodies, which, on account of their reſemblance to the external form of plants, with the hardneſs of ſtone, were

formerly called LITHOPHYTA, or ſtony plants,—as coral, and a variety of other bodies of the coral kind, or allied to it, which later naturaliſts ſuppoſe to be the work of animals, or to be produced in the ſame manner as ſhells. And a late author, Pallas, who has written particularly upon this ſet of productions, repreſents them in a ſtill more curious light. Hence they are called ZOOPHYTA, or animated plants. Whatever may be their nature, and in whatever manner they may be formed, they are compoſed, like the ſhells, principally of calcareous earth; and there is a very great variety of them in reſpect of form and appearance. Some are ſpread like a cruſt upon ſtones and other ſolid bodies, and full of microſcopic pores inhabited by animals,—MILLEPORA; others are protuberant maſſes; others an aſſemblage of pipes,—MADRIPORA; others are branched,—CORALS. Theſe are full of animals.

Under theſe four forms now deſcribed, the calcareous earth has generally a great degree of purity; and in ſome of them, perhaps, is perfectly pure,—that is, unmixed with any other earth. But there are alſo ſome foſſil earths, which, though they be not compoſed entirely of calcareous earth, but, on the contrary, contain ſometimes but a moderate portion of it, deſerve, however, to be mentioned here, on account of their uſefulneſs and importance. Theſe are the earths called MARLES, which have been long ſucceſsfully employed as manure to improve ſoil. Every ſubſtance to which the name of marle is properly applied, and which proves of general uſefulneſs as a manure, contains more or leſs calcareous earth; and is uſeful and valuable in proportion to the quantity it contains.

Marles are commonly divided into three kinds,—SHELL MARLE, CLAY MARLE, and STONE MARLE.

1*ſt*, Shell marle is compoſed of the ſhells of ſhell-fiſh, or other cruſtaceous aquatic animals, lying together in immenſe quantities. Many are entire, but in general they are decayed, and moſtly mouldered down to duſt, and intermixed with more or leſs ſand, or other earthy ſubſtances. When we examine this matter, as occurring in different

places, it may be diſtinguiſhed into two kinds,—freſh water marle, or bog marle, and ſea-ſhell marle. We have an example of bog marle in the Meadow, compoſed of the ſhells of the ſmall freſh water wilk or ſnail, which multiply greatly in lakes or ponds, or brooks of freſh water, and of other ſhells, which are gradually depoſited in great collections by the water. The other kind of ſhell marle, the ſea-ſhell marle, conſtitutes much greater collections, which are found in many places, though at preſent far removed from the ſea. One of the moſt noted examples has been deſcribed by Mr. Reaumur, in the Memoirs of the Academy *.

2*dly*, Clay marles conſiſt of earths of different colours, which more or leſs reſemble, and actually contain clay; but with it ſome calcareous earth is mixed, in fine powder like chalk.

3*dly*, Stone marles are of very great variety in colour and appearance. They are harder and more ſtony than clay marles, and that is the only diſtinction between them; but they differ from maſſes properly ſtony in this, that by being only a few weeks or months expoſed to the air, they ſplit into pieces, and crumble down into earth, or a matter like clay. Some, however, take a long time to break down in this manner; and there is all the variety poſſible in this reſpect between them and the clay marles. This diſpoſition to moulder down by the weather, depends on the admixture of clay, which they contain. A conſequence of the gradual, though very ſlow diſſolution of this earth by water, has been obſerved in the ſtrata of hard marles. It

* Of the Fahlun or marle of Touraine. This diſtrict, of 80 ſquare miles, is more than 36 leagues diſtant from the ſea, and is every where filled with marle. It is found about eight or nine feet from the ſurface, and they dig it to the depth of 20 feet. The marle is ſtill deeper, but it is too expenſive to follow it. One gentleman, from curioſity, penetrated 18 feet, and did not know how much farther it might extend. Suppoſe it is of no greater depth, it would contain above 130 millions of cubic fathoms. It is totally compoſed of ſhells, ſome of which are entire, but they are generally decayed, or broken into fragments, and mixed with other marine productions, ſuch as coralines, millepores, madrepores, &c.

has been found by experience, that ſuch ſtrata do not contain any calcareous earth where they crop out, on the ſurface of the ground, nor even at the depth of a few feet below this. Many gentlemen who were in poſſeſſion of a ſtratum, which they knew, from the neighbourhood, to be a rich ſtone marle, have, without fear, expended great ſums of money, and covered much of their land with this crop marle. They not only loſt their money, but, in many caſes, ſpoiled their land, by filling it with a hard baking clay. This effect upon beds of marle is without exception; and it is even found that the upper plates of ſingle ſtrata of limeſtone are deteriorated in the ſame way. This fact alſo explains, by the way, the wearing out of lime uſed as a manure upon land.

When we now examine with attention many of theſe natural collections of this ſort of earth, we are led to a concluſion which may appear ſurpriſing at the firſt hearing of it; but which is founded on a multitude of the moſt authentic facts.

The inference I mean is, that all the large collections of calcareous earth have derived their origin from ſhells and lithophyta, or that they were once in that form. The proofs of this are ſo numerous and ſtriking, that they cannot be reſiſted.

1. Beds of ſea ſhells, or other calcareous productions of the ſea, are found in many parts of the world, of great extent, and in all the different ſtates of decay.

2. We find abundance of ſhells, or fragments of ſhells, and of zoophytes, in the greateſt number of the calcareous ſtrata of marbles, limeſtones, and chalk; which are the greateſt collections of calcareous earth.

We do not find ſhells in calcareous ſpar, nor in ſtalactites; but it is evident that theſe forms of the calcareous earth have been completely fluid, ſo that all the organic ſtructure of the original matter is neceſſarily loſt.

There are alſo many marbles and limeſtones, in which we do not find any of the appearances I ſpeak of. But this too can be explained,

by examining their ſtructure or aggregation, which ſhews that the matter of them has been diſſolved or liquefied by other operations of nature *. Another cauſe of the non-appearance of ſhells and lithophyta in ſome collections of calcareous earth is, that the ſhells have been broken and worn down into fragments like ſand, or even reduced to powder, by agitation and attrition, upon the coaſts, or by other cauſes. This ſeems to be the caſe of chalk. There is another example of this kind in England, in the Bath ſtone and Portland ſtone, which are calcareous: And ſimilar ſtones occur in many parts of the world. There are ſome few entire ſhells found in theſe ſtones; but the greater part of it does not exhibit any.

The abundance and great extent of the ſtrata of calcareous earth are, therefore, a proof of the great antiquity of this globe, and of the great changes which have happened in its ſurface.

In ſome few places the bones of land-animals have alſo been found, in very conſiderable quantities, mixed with calcareous matter; as in Dalmatia, and ſome iſlands of the Adriatic; at Gibraltar, in Spain, and in France †.

In whatever condition the calcareous earth is found, it is eaſily diſtinguiſhed from other earthy ſubſtances, by effervеſcing with acids; and, when it is not very impure, by becoming common quicklime, when expoſed for ſome time to the action of a ſtrong fire.

In making the trial with acids, however, it is neceſſary that the perſon who makes it ſhould underſtand it well, as I have known many who never had ſeen or attended to real effervеſcences impoſed upon by the appearance of it. I have often had earths ſent me by farmers,

* The rapidity with which the coral rocks in the Pacific Ocean are formed, by the little animals, is altogether aſtoniſhing; and it is evident to the ſight.

† *Memoires ſur les oſſemens foſſils qui ont appartenus à des grands animaux: Obſervations de Phyſique, Mai* 1781. The author is of opinion that they are not the bones of elephants, but of ſome large aquatic animals which have inhabited the lakes and great rivers, or rather the ſea. His obſervations render this very probable. The memoir is curious, and deſerves a careful peruſal.

or country gentlemen, as calcareous marles, which they aſſured me effervefced, or fermented with vinegar, and diſſolved in it too; but which, when I tried them, ſhewed not the ſmalleſt effervefcence. Upon deſiring them, therefore, to ſhew me the fermentation and diſſolution they ſpoke of, I found that they had throwu the earth dry into the vinegar, and that what was taken for effervefcence, was the expulſion of a ſmall quantity of common air which was contained in the pores and vacuities of the dry earth, and which aroſe ſlowly in little bubbles, when the fluid was ſucked into theſe pores; and the ſuppoſed diſſolution was the diffuſion of the earth. Remember, therefore, always to ſoak and moiſten with water before the acid be applied.

In deſcribing the properties of the objects of chemiſtry, I begin commonly with the effects of heat; but, as this earth, in conſequence of the ſtate in which it is found in nature, undergoes a very great change in all its chemical relations by the action of a ſtrong fire, I ſhall firſt notice its properties with regard to mixture, in its ordinary or native ſtate.

I have already remarked that the action of acids on it is very ſimilar to their action on alkaline ſalts. Let us, therefore, attend to the manner in which it unites with each of the different acids.

The firſt of theſe, therefore, the ſulphuric acid, attaches itſelf to this earth with great rapidity, and violent effervefcence. Thus, when we throw powdered chalk into diluted ſulphuric acid, violent effervefcence is produced; but the chalk, however, is not diſſolved. It renders the liquor thick and muddy; and, if allowed to reſt, falls to the bottom in the form of a ſediment much more bulky than the chalk alone. The reaſon of this is, that the compound produced by the union of the ſulphuric acid with calcareous earth has very little ſolubility in water. It requires a very large quantity of water to diſſolve it, 500 times its weight at leaſt. Hence, not finding water enough in the mixture, the greateſt part remains undiſ-

ſolved, and is more bulky than the chalk, becauſe it conſiſts of that chalk and the ſalt which it has formed with the ſulphuric acid. This compound was formerly called GYPSUM or SELENITES, or the Selenitic Salt. The name now given to it, by the French chemiſts, is SULPHAT OF CALCAREOUS EARTH, or SULPHAT OF LIME. It is formed naturally in conſiderable quantities in the bowels of the earth, and is valued on account of ſeveral uſeful properties which belong to it. Theſe we ſhall mention more fully afterwards.

Although this compound is difficult to diſſolve, and requires much water to its diſſolution, it can, however, be completely diſſolved, when enough of water is applied to it, viz. one ounce for each grain; and when the water is evaporated, the compound concretes into numerous ſlender and ſmall cryſtals, as fine as hairs, which ſubſide and form a white ſediment. A ſmall portion of this ſalt is the general impurity of thoſe ſpring waters which are called hard waters.

Such is the action of the ſulphuric acid upon this earth, in the form of powder. But it does not operate upon it ſo readily in its ſolid and compact form, becauſe the ſurface is neutralized, and protects the interior parts from the corroſion of the acid.

None of the other acids, hitherto deſcribed, form inſoluble or difficultly ſoluble compounds with this earth, except the tartarous acid, which forms with it the compound called by Mr. Scheele *ſelenites tartareus*, now named the tartrite of lime *.

The other acids, viz. the nitric, muriatic, and acetous acids, form with it very ſoluble compounds; and all of theſe acids too, as I before obſerved, are attracted by the earth in the ſame order as they are attracted by the alkali; and therefore, if the ſulphuric acid be added to the ſolutions or compounds formed by any other acid, it immediately

* It forms inſoluble compounds alſo with the phoſphoric, malic, and ſome other acids.

EDITOR.

diſengages the other acid, and unites itſelf to the earth, in conſequence of its ſtronger attraction, forming with it the ſulphat of lime already deſcribed, which therefore precipitates or falls to the bottom.

The calcareous earth not only has a ſtronger attraction for the ſulphuric than for other acids, but, further, ſome experiments ſhew that it has a greater partiality (ſo to call it) for this acid above others, than the alkalis have. This I think appears from what happens when we mix any compound ſalt containing the ſulphuric acid, with a compound or ſolution of the calcareous earth in any other acid than the ſulphuric. Thus, if we mix a ſolution of Glauber's ſalt, or ſulphat of ſoda, in hot water, with ſome of the ſolution of calcareous earth in nitric acid greatly diluted, the mixture will become muddy, and depoſit a ſediment. There is therefore a double elective attraction. *(See Bergmann).*

There are only two of the acids already deſcribed, which, as I learned by ſome experiments made on purpoſe, have not power to act on the calcareous earth in its natural ſtate. Theſe two acids are the ſedative ſalt or boracic acid, and the ſulphurous acid *(acidum ſulphuroſum)*, or acid of ſulphur in its volatile ſuffocating ſtate. And to theſe we may add ſulphur itſelf, which was ſpoken of in treating of the ſulphuric acid. Theſe three chemical bodies, the boracic acid, the ſulphurous acid, and ſulphur itſelf, are but weakly attracted by alkaline ſubſtances in general.

With regard to the other claſs of ſimpler ſalts, the alkalis ſhew as little diſpoſition to act on calcareous earth as on one another. The only obſervation that belongs to this head is, that they have a ſtronger attraction for acids; and when mixed with ſolutions of the calcareous earth, immediately precipitate it,—uniting themſelves to the acid in its place. And the effect is the ſame whether we uſe a fixed or a volatile alkali in their ordinary ſtate. It ſhould alſo be remarked, that when an alkali is employed to diſlodge calcareous earth from an acid, *we have no effervescence.*

Such is the relation of the calcareous earth to the acids and alkalis.

Of the compound ſalts, none are affected by it except tartar, and the ammoniacal ſalts. Tartar, when boiled with it, is neutralized, or, to expreſs it more properly, it is deprived of its ſuperfluous acid. And the ammoniacal ſalts can be decompounded by it, but only when it is aſſiſted by heat.

If, for example, we mix chalk with common ſal ammoniac,—the muriat of ammoniac; either taking this ſalt as diſſolved in water, or in the form of very fine powder, we cannot perceive any change or effect produced, however long they remain ſimply mixed together. But if they be mixed in the form of fine powders, and we then apply heat to this mixture, as ſoon as the heat increaſes to a certain degree, the ammoniacal ſalt begins to be decompounded. The acid of it is joined to the calcareous earth; and the volatile alkali ariſes into the receiver in large quantity, and forms a very ſolid ſaline cruſt on its internal ſurface. The proceſs is as eaſy as the diſtilling of water. The veſſels are to be luted with chalk made into a thin paſte, with mucilage or gum-water. The heat may be ſlowly raiſed till the ſublimation begins to dim the veſſels, and then kept in that ſtate; and the operation ſtopped whenever a dimneſs appears in the top or neck of the retort. This indicates a commencing ſublimation of the ſal ammoniac, if too little chalk has been employed.

This proceſs for decompounding ſal ammoniac by the action of chalk and a ſtrong heat, is often performed in England, to obtain a volatile alkali for the purpoſes of medicine. The alkali thus obtained is remarkably ſolid and dry, and in larger quantity than that which is got from the ſame quantity of ſal ammoniac, when it is decompounded by a fixed alkali.

Theſe are the properties of the calcareous earth with regard to mixture in its natural ſtate.

But it ſuffers a remarkable change by the action of fire on it, which is next to be deſcribed.

If it be expoſed to the action of a ſtrong red heat for ſome time, it becomes what is well known by the name of QUICKLIME. For this purpoſe, the marble, limeſtone, or chalk, is broken into pieces of ſmall ſize, and piled up in a kiln built in the form of an inverted fruſtum of a cone, mixed with a proper quantity of fuel, taking care to have a ſufficient quantity of fuel at the bottom, to raiſe a heat in the beginning; and alſo taking care that the whole may be ſo piled up, with ſpiracles properly conducted through it, by laying the materials open in thoſe places, that the heated air may have a current pretty equably diſtributed through the whole maſs. This ſoon kindles the interſperſed fuel all over the kiln; and it would ſoon become ſo hot as to riſk the melting of impure limeſtone, were it not checked by contracting the apertures by which the air gets in below, or (if it be a ſimple clamp kiln) by covering the whole at top with earth. The proper degree of heat muſt be learned by trials; it being different according to the nature of the limeſtone and alſo of the fuel. Some pit-coals have a great tendency to vitrify even the pureſt limeſtone; and limeſtone containing iron in any ſtate is very much diſpoſed to vitrification. It is only experience which can teach how much fuel is required for raiſing the due heat, and for continuing it till all ſhall be calcined. If it be a clamp kiln, the fire is allowed to burn out, and the quicklime is taken out when the kiln is ſufficiently cooled. But limekilns are more artificially conſtructed, ſo that the work is never ſtopped. The calcined lime is taken out at an opening properly contrived below, by which the whole ſubſides; and the limeſtone is continually added above, mixed with baſkets of fuel. The fuel is entirely conſumed in the lower and narrower part of the cone; and the great heat of the glowing blocks of quicklime maintains the current of freſh air through the interſtices, and cauſes it to arrive at the unconſumed fuel above, in a ſtate fit for continuing the combuſtion. The conſumption of the fuel is vaſtly ſlower than would happen were it interſperſed in the ſame

manner among lumps of free-ſtone or pebbles, for reaſons which you will ſoon underſtand.

When we want to prepare a ſmall quantity for experiments, we juſt mix it with abundance of fuel, in any ordinary furnace, and urge it with the greateſt heat, which will not vitrify it when impure. Pure limeſtone, marble, or chalk, may even be calcined in a crucible, without touching the fuel; but this requires a very great heat, long continued.

Quicklime has a number of qualities different from thoſe of the natural calcareous earth. If it have been hard before, it becomes more friable and porous, eſpecially the pureſt kinds. It alſo loſes a very great part of its weight, 40 per cent. in the pureſt kind. This great loſs is well known to thoſe who have occaſion to fetch lime from a diſtance; and it is the beſt mark of complete calcination. Further, from being a mild, inſipid, and inert earth, we find it now an active and acrid ſubſtance, like the alkaline ſalts. It ſhews a very conſiderable degree of activity in mixture with a variety of other bodies. Applied to the tongue, it is extremely acrid, giving a taſte very much like an alkaline ſalt. If left any time upon a moiſt ſucculent part of animal or vegetable ſubſtance, it either corrodes and diſſolves it to a pulp, or weakens the coheſion of it to a great degree; and it has the ſame effect on the moſt ſolid and firm parts, if it be made into a ſoft paſte with water before it is applied. This ſhews that it has a ſtrong chemical attraction for the matter of thoſe ſubſtances. We diſcover in it alſo a ſtrong attraction for water. This attraction is one of the moſt remarkable qualities by which it differs from calcareous earth in its native ſtate. Thus, when we pour water upon the lime, a quantity of it is quickly ſucked up into the pores of the ſtone; and, after a ſhort time, the maſſes of quicklime which we have moiſtened begin to grow warm, and to ſmoke. They ſwell, ſplit, and crumble down into pieces; and theſe are affected in the ſame manner, until the whole, in a few minutes, is converted into a ſubtile white powder,

greatly more bulky, and which, if too much water have not been uſed, is perfectly dry and duſty. While this is going on, it becomes ſo hot, that a part of the water is evaporated in boiling hot ſteams; and if the quantity of lime ſo wetted at once is much greater than this, the heat increaſes to a degree capable of inflaming combuſtible bodies. If a ſtick, for example, be thruſt into a large heap of it, the extremity will be burnt to a black coal. Leaky ſhips have ſometimes been unfortunately ſet on fire at ſea by a cargo of quicklime. This is ſo well known, that when they venture to load with it, they take every precaution to prevent ſuch a misfortune.

As ſoon as the lime has been thus reduced to a ſubtile powder, by a ſufficient quantity of water, no more heat is produced. It cools and does not produce heat again if mixed with water. It is called SLAKED LIME,—CALX EXTINCTA. If we weigh it, we find it conſiderably heavier than before the water was added to it. This addition of weight is from a part of the water now cloſely united with it; every particle of the lime having its due proportion. The water thus united with the lime is retained by it with a ſtrong attraction; and cannot be ſeparated again without a red heat. Being in a ſolid form, the emerſion of the latent heat, which occaſioned its fluidity, is the ſource of that great heat which is produced during the ſlaking of the lime, and affords one of the moſt remarkable inſtances of this emerſion. But if ſuch a heat is applied to the ſlaked lime in a retort and receiver, we recover the water in its former ſtate. The lime from which it is ſeparated becomes quicklime again, and is diſpoſed to produce the ſame effects with water as before. Theſe effects, therefore, evidently depend on a ſtrong attraction which the lime and water have for one another. And ſlaked lime is lime ſaturated with water, or combined with as much water as can unite with it, ſo as ſtill to form a dry compound. The conſequences of this union with water, however, are not ſuch as to take away the attraction of the lime for other ſubſtances. It has the ſame acrid taſte as before, and the

ſame, or even a greater corroſive and diſſolving power, with reſpect to a variety of different ſubſtances. Nor is its attraction for water ſaturated by this ſolid combination. It ſtill manifeſts a ſolubility in that fluid, perfectly reſembling, in this reſpect, the relation of cryſtallizable ſalts to water. They, after having combined wit ha certain quantity, are diſſolved in a larger quantity. This ſolution is perceived when we mix ſlaked lime with a much larger quantity of water, or dilute it largely in water. If we examine this water, we ſhall find that it has either diſſolved a part of the lime, or extracted ſomething from it, ſo as to form a clear ſolution like that of the alkaline ſalts, and reſembling them much in taſte.

This is the fluid called LIME-WATER, the nature and beſt preparation of which was, ſome time ſince, a ſubject of much diſputation in this place. The general opinion was, that the production of the lime-water depended on an active and ſubtile principle, extracted by the water from the lime, which was imagined to contain only a ſmall portion of it; and that the lime could therefore make only a moderate quantity of good lime-water, ſuch as 10 or 12, or at moſt 20 times its weight.

It is known now that a much greater quantity of good lime water can be made of lime,—that is of a good quality; perhaps 300 or 400 times its weight. And the proceſs for making good lime-water is ſo ſimple, that it was thought unneceſſary to inſert it in the former editions of the Edinburgh Pharmacopœia. But a proceſs was given for it in the laſt edition, viz. 1*mo*, Slake the lime with a ſmall quantity of water, about one fourth or one-third of its weight, and let this be done in a veſſel of earthen ware or glaſs, keeping it covered while the lime is ſlaking: 2*do*, Pour on it 30 or 40 times its weight of more water, and after agitating to diffuſe the lime through the water, cover up the veſſel again. The agitation being repeated afterwards 10 or 12 times to promote the diſſolution, we may then allow the remaining lime to ſubſide, and filtrate the lime-water, to have it clear. Thus lime-water

is made as ſtrong as poſſible. But, in its ſtrongeſt ſtate it contains but a ſmall proportion of the lime, or limy matter. I made experiments to aſcertain this point, and found, that the ſtrongeſt lime-water we can make does not contain a larger proportion of lime than one part in 500 parts of the water. It has, however, a pungent, acrid, diſagreeable taſte, reſembling that of the alkaline ſalts; and has alſo the power to change the vegetable colours like thoſe ſalts. A moderate quantity produces firſt a ſea-green; a little more, a graſs green; and more ſtill, a yellow, or fillemot, attended with muddineſs; the colouring matter being corroded and deſtroyed. It is the moſt tranſparent fluid known.

Such are the effects of water mixed with lime in different ways.

When we next try the effects of acids, we find that lime is ſtill more diſpoſed to unite with theſe, than the calcareous earth was when in its natural ſtate. It unites much more quickly with the vegetable acids. Diſtilled vinegar, which diſſolves the calcareous earth but ſlowly, diſſolves lime readily and quickly. And when we boil lime with a ſolution of tartar in hot water, the lime takes to itſelf the whole acid of the tartar, not the ſuperfluous acid alone, which only is ſeparated from the tartar by the calcareous earth in its natural ſtate.

Further, lime can be joined with the boracic and ſulphurous acids, ſo as to form a borat and a ſulphite of lime; neither of which can be produced from the natural calcareous earth. And when we mix lime with the muriat of ammonia, it ſhews ſuch a ſtrong propenſity to unite with the muriatic acid, that it decompounds the muriat the moment they are mixed together, not requiring the aſſiſtance of a ſtrong heat, which is required by the natural calcareous earth.

Beſide the quickneſs and facility with which lime decompounds the ammoniacal ſalts, the volatile alkali, which we obtain from the mixture by diſtillation, is in an uncommon and very remarkable ſtate. When heat is applied, this alkali ariſes in vapours which are in the higheſt degree elaſtic, pungent, and penetrating. They cannot be

condenſed without the aid of ſome water to repreſs their volatility by its attraction. Were we to neglect the proper application of water to this mixture, for the purpoſe of condenſation, this alkali would continue in the ſtate of an incondenſible elaſtic fluid or gas. This is what Dr. Prieſtley called alkaline air, and made the ſubject of many experiments. One of them is very pretty and amuſing. If ſome of this vapour be mixed with that of the muriatic acid, we have immediately a precipitation of ſal ammoniac. If this experiment be made in the modern pneumatic apparatus, a diſagreeable accident ſometimes happens. The vapour of either being ſuddenly mixed with the other, in the upper part of a jar, ſtanding in water or mercury, the whole collapſes in an inſtant, and the water or mercury daſhes againſt the top of the jar with ſuch force, as to beat it up to a conſiderable height, and with riſk to the operator.

When we do employ water, though in no greater quantity than what is abſolutely neceſſary, no part of the alkali ever is condenſed into a ſolid form. It always conſtitutes, with the water, an highly pungent, acrid, volatile, alkaline fluid.

A volatile alkali is ordered to be prepared in this ſtate, in both the London and Edinburgh Pharmacopœias. It was formerly named *Spiritus Salis Ammoniaci cum calce vivâ.* Now it is named *Aqua Ammoniæ puræ,* for a reaſon which you will ſoon underſtand.

Various proceſſes have been recommended, by different authors, for preparing it in the beſt and moſt convenient manner. Some have adviſed to put the quicklime into the retort unſlaked, and then pour on it the ſal ammoniac diſſolved in water. But this mode is inconvenient, cauſing ſudden and violent heat, which makes the volatile alkali riſe ſo impetuouſly, and in ſuch incoercible vapours, that the greater part of it is loſt. In diſtilling it, a very gentle heat is abſolutely neceſſary, that time may be allowed for its condenſation, by means of its union with the water that is to aſſiſt in condenſing it. It requires much caution and patience to accompliſh this,

becauſe the alkali riſes in vapour more readily than the water, and does not carry off with it a very conſiderable portion. And, ſhould we attempt to promote the condenſation by putting water into the receiver, we ſhall ſtill be diſappointed, becauſe the alkali combined with the water merely ſufficient for its condenſation, forms a fluid conſiderably lighter than water, which will, therefore, float on the ſurface of that in the receiver, and this, being already ſaturated with alkaline vapour, will condenſe no more. I mention this particularly, becauſe ſimilar things frequently occur in diſtillations; and muſt be carefully attended to, to avoid accidents. Mr. Woulfe's method obviates this difficulty; but is beſt adapted to the diſtillation of large quantities.

After having tried different methods, I now practiſe one which does not require this complicated apparatus, and ſerves very well for preparing a ſmall quantity of this alkali. Having put the ſal ammoniac, in lumps, into the retort, pour on it a mixture of an equal quantity of lime, and thrice its weight of water, ſtirred till uniformly mixed, and kept till cold. The volatile alkali begins immediately to be ſeparated in pungent vapour: But, as there is enough of water preſent to repreſs and moderate its volatility, the vapours are not troubleſome. Now apply the receiver, which has firſt been well warmed, to rarefy the air, and thus expel a part of it; and immediately cloſe up the joining of the two veſſels, ſo as to make that joining perfectly air-tight. This is done by firſt applying common putty, made of chalk and linſeed oil. But as this paſte, though impenetrable to air, is in ſome degree ſoft, and would be forced open by the preſſure of the elaſtic vapour from within, we may ſecure it from this accident by putting over it another luting, which will ſoon grow quite firm and hard, and will bind the putty ſtrongly in its place. This other luting is a mixture of chalk and gum-arabic,—nine parts of the chalk to one of the gum. It muſt be made into a fluid paſte with water, and ſpread on ſlips of paper, and theſe put

on the joint. Being then brought into close contact with every part of it by a ligature or bandage, it makes the joint so close and strong, that the vessels would be burst open in any other part of them sooner than in this. The joining being thus made perfectly air-tight, it is evident that we must be very cautious in applying the heat to perform the distillation. Too much heat would certainly burst the vessels, by giving too much elasticity to the air and vapours; and it would also bring over too much of the water, supposing the vessels were strong enough to withstand it. We, therefore, apply a very gentle heat, and apply it so long only as may be necessary for obtaining the product in proper quantity. Thus the alkali, and a portion of the water, will distil over together, slowly and imperceptibly, until we have enough of it, which will be the case when the heat shall have continued 24 hours. *(See Note* 1. *at the end of the Volume.)*

Beside this action of quicklime on muriat of ammoniac, and other qualities of it which we mentioned, a further particular, which shews that its powers as an alkaline substance are increased, is its effect on sulphur. It is capable of uniting with it in the dry way, by mixing it in powder with the sulphur, and applying such a heat as converts the sulphur into vapour, or melts it.

But a more convenient way is to join them in the way of solution, or *viâ humidâ*. Equal weights of sulphur and quicklime must be mixed in a flask, and a quantity of water added boiling hot. The mixture must be boiled for some time, and then more boiling water added, and the boiling repeated. After standing a proper time for subsidence, the clear liquor must be decanted into a phial, which must be carefully stopped. This gives a perfect compound of sulphur and lime.

The compound we thus obtain is called the sulphuret of lime,—*sulphuratum calcis*. It is incomparably more soluble in water than the lime alone, and it has the same yellow colour and disagreeable odour,

that is ſo ſtrong in the compounds of ſulphur with alkaline ſalts. The union of the two ingredients of this compound is ſimilar to that of the alkaline ſulphuret. It is decompounded by expoſition to the air, and in its place we obtain gypſum or ſelenite, compoſed of the ſulphuric acid and calcareous earth. Moreover, this decompoſition is accompanied by the abſorption of oxygenous gas, leaving only the mephitic air of Scheele, or the phlogiſticated air of Prieſtley. Indeed, it was with this ſulphuret that Scheele made his firſt experiment. Like the alkaline liver of ſulphur, too, it is decompounded by any acid. The nitrous acid does not diſengage from it the hepatic or ſtinking gas, without ſome particular attentions, which will be mentioned afterwards.

All theſe facts and experiments ſhew that lime has a ſtronger tendency to unite with other bodies than the calcareous earth has when in its natural ſtate.

The moſt remarkable property of lime appears in the change which it ſuſtains by mixture with the alkaline ſalts, and the change which it induces on them. This conſtitutes the chief difference between quicklime and the natural or crude calcareous earth. If we mix it properly with an alkaline ſalt, the lime immediately loſes its activity and corroſive nature, and becomes quite mild, inſipid, and no longer ſoluble in water. To illuſtrate this, we may notice the effects of an alkali upon lime-water. This fluid, as I obſerved before, contains but a ſmall proportion of limy matter diſſolved in the water, about one grain to the ounce. Yet, upon dropping into it a ſmall quantity of diſſolved alkaline ſalt, it inſtantly becomes muddy, and depoſits the lime in the form of mild inſipid calcareous earth. And the effect is ſimilar when we uſe, inſtead of lime-water, a muddy mixture of lime and water, or a quantity of water with more lime in it than it can diſſolve into lime-water. Provided we add to ſuch a mixture a ſufficient quantity of the alkaline ſalt, both the diſſolved part of the lime, and that which, for want of a ſufficient quantity of water, is not diſſolved, will be im-

mediately rendered mild, inactive, and incapable of being diſſolved by pure water.

Here is, therefore, a ſudden reſtitution of the lime to its original ſtate of a mild, inactive, inſoluble earth; for when we collect and dry the mild earth thus obtained, we find it has every property of the calcareous earth, in its natural or ordinary ſtate, and may again become lime by calcination.

But, further, when this change is produced in the lime, the alkali ſuffers one which is as remarkable. This is perceived when we ſeparate the alkaline liquor again from the lime, and examine this liquor, or by evaporation obtain the alkali again in a dry ſtate.

We find it incomparably more fuſible than before. It is melted long before the heat of it is raiſed to the degree of ignition.

Moreover, it becomes more ſuſceptible of vaporiſation. A very ſenſible quantity is carried off by haſty boiling the ſolution of it in water; and if long continued in a red heat, with ſpongy matters to prevent its melting, it evaporates very faſt, and is loſt.

We find alſo that its acrimony, or activity to diſſolve different ſubſtances, is very greatly increaſed. In the treatment juſt now mentioned,—the melting of it by heat,—it often happens, that by raiſing it to a red heat, it diſſolves the earthen veſſel in which it is melted.

Alkali, rendered more active in this manner by lime, is much employed in ſome of the arts, and, being alſo uſed for ſome purpoſes in medicine, is ordered to be prepared in both our pharmacopœias.

Three parts of alkaline ſalt, and four parts of perfect quicklime, are to be ſuddenly mixed in twice their weight of water. This will produce great heat and ebullition. The veſſel muſt be covered, and the mixture agitated repeatedly. It muſt then be poured into a filtrating funnel, which is ſet into a phial, or other veſſel, proper for holding the lixivium. After it has ceaſed running through the filtre, water muſt be poured on a-top, and allowed alſo to run through the filtre, till the whole lixivium is about thrice the weight of the ſalt and

lime. It will be without colour or ſmell, if theſe have been pure, and muſt be kept in bottles cloſely ſtopped. The water may be expelled by heat. When the boiling has ceaſed a little while, the purely ſaline part remains fluid like fluggiſh oil, and the veſſel is, at this time, almoſt red hot. When poured out on an iron plate, it quickly congeals, and may be divided, while very hot, into pieces fit to go into the mouth of a phial, where it may be kept ſhut up from the air. This is the *alkali cauſticum acerrimum* of the Diſpenſatory. The *cauſticum mitius* is made by pouring the melting ſalt on quicklime, and mixing before it cools.

The advantages of this proceſs are, 1*ſt*, The lime, being ſlacked with unuſual violence, is the more ſubtilely divided. 2*d*, The heat promotes the action of the lime and alkali. 3*d*, The ſmall quantity of water uſed alſo promotes their action; the lime not having room to ſubſide.

Here I muſt mention a circumſtance which I am not yet able to explain; namely, that this cauſtic ley has a ſingular effect on the earthen-ware veſſels in which it is kept. I always uſed veſſels of that kind of pottery called in this country ſtone-ware, which is a ſpecies of porcelain, far ſuperior to the ſoft bibulous pottery. I have very often obſerved that, after two or three months keeping in ſuch veſſels, they ſplit all over, with a loud crack. The ſame obſervation has been made by other perſons of my acquaintance. Nor is this confined to this particular material; it happens alſo to glaſs bottles, though not ſo frequently. The only conjecture that I can form on the ſubject is, that the alkalis, acting on the inner ſurface of a veſſel not well annealed (and it is ſcarcely poſſible that any can be *perfectly* annealed) corrodes the ſtratum which ſerves to ſupport the whole in its ſtate of unequable contraction. Yet I could not ſee any ſuch corroſion.

I have alſo obſerved, and my obſervation was confirmed by Dr. Irvin, that cauſtic ley, very long kept, loſes its acrimony, and that its alkaline properties are really impaired, as if the ſalt had evaporated

from it, or that it was neutraliſed by ſome other ſubſtance. You will notice that I ſuppoſe it all the while to have no communication with the air.

Dr. Alſton made an obſervation on cauſtic leys, which is curious, and of which I do not ſee any explanation. The ſpecific gravity of an alkaline ley is conſiderably diminiſhed by adding lime to them. This effect is very remarkable in the ſolution of volatile alkali.

The activity of the alkali to diſſolve animal and vegetable ſubſtances is now increaſed to a ſurpriſing degree; ſome of the firmeſt parts of animals being ſoon diſſolved by it into a pulp. Hence it is often uſed externally in ſurgery, for opening abſceſſes, deſtroying fungous fleſh, or making iſſues in the ſkin, when the patient is afraid of the knife. It acts with burning pain: Hence it is called the POTENTIAL CAUTERY, or the CAUSTIC ALKALI. Notwithſtanding this high degree of acrimony, it has been uſed of late internally; but it muſt be greatly diluted and obtunded, by which means the foſſil acids themſelves may be taken internally with ſafety.

Such is the activity of the cauſtic alkali with reſpect to animal ſubſtances. Of the vegetable there are many which it will penetrate and diſſolve as readily. But the dry or pure woody fibres of vegetables ſuſtain its action for ſome time. Of this woody or fibrous matter, cotton, bleached linen, paper, and the like ſubſtances, are compoſed. Even theſe, however, though they are not diſſolved, are corroded, or made tender by it, and their coheſion much diminiſhed, as has often happened to linen cloth in bleaching. The two fixed alkalis acquire juſt the ſame activity from lime, and have the ſame effect upon lime. The volatile alkali likewiſe produces the ſame effect upon the lime, in reſtoring it to its mild ſtate; and is affected itſelf much in the ſame way as the fixed alkalis are, if allowance be made for its different nature. Its volatility is prodigiouſly increaſed, as I have already obſerved; and it is now incomparably more acid and pungent, ſo that it muſt be ſmelt to with great caution, otherwiſe it will excoriate and

deſtroy the noſtrils. Like the cauſtic fixed alkalis, it diſſolves animal and vegetable ſubſtances into a pulp; and acts on oils and fats in the ſame manner, making them miſcible with water; in ſhort, rendering them ſoaps. It becomes preciſely the ſame with the *ſpiritus ſalis ammoniaci cum calce vivâ.* As in that preparation the vapours are incondenſible without water, ſo, when as little as poſſible is uſed, they are inſeparable by diſtillation. Mr. Du Hamel imagined that the volatile alkali was deſtroyed by repeated additions of lime; but this is a miſtake, owing to the eſcape of part of it at each addition, by the ſudden eruption of incoercible vapours, in conſequence of the heat produced by the addition of the lime.

I have now deſcribed the more remarkable properties of quicklime in the way of mixture. I muſt now obſerve that when it is expoſed to the air, it begins, after ſome time, to ſwell, ſplit, and crumble down, until it is ſlowly reduced to as fine a powder as when it is ſlaked with water. This happens to it plainly in conſequence of its gradually attracting humidity from the air, until it has received enough to ſaturate it, or to convert it into ſlaked lime. But the lime ſlaked in this manner is not ſo acrid and active as that which is ſlaked immediately with water, and without being much expoſed to the air. The air, at the ſame time that it ſupplies humidity to it, is alſo found to weaken its force by degrees, and continues to weaken it more after it has been completely ſlaked, until, in a certain length of time, it deprives it of the qualities of quicklime altogether, and reduces it to the ſtate of inſipid calcareous earth.

The lime does not undergo this change when it is preſerved in cloſe veſſels. It ſuffers it only when we expoſe it to the free air, or when we keep it in veſſels that are left open. And we further find, that the more wide and looſely it is ſpread out to the air, it becomes inert ſo much the ſooner. It loſes its activity faſter, in proportion to the more extenſive contact or communication of the free air with it.

But, if the lime be made into a paſte with water, and this paſte be

collected and compacted together in the form of a round mass, it then retains its activity, and the other qualities of lime, much longer than when it is exposed to the state of a dry powder, and spread out to the air: And the reason is plain. When it is in the state of a paste, the water, filling up the interstices between the particles, excludes the air from among them; and only those that are at the outside of the wet mass can be affected by it.

Lime-water is also liable to a similar change by exposition. It may be preserved in the same manner for a long time in close vessels, without alteration of its qualities. But if it be left in an open vessel, we may see, in a few minutes, a thin film produced upon its upper surface, where it is in contact with the air. This film continues to increase in thickness, until, after a number of hours, or perhaps a few days, it will form a thin stony crust. In proportion as this crust is formed on the top, the water below loses its taste and the other qualities of lime-water, and at last becomes a mere insipid water. The crusty matter itself, on examination, proves a mild calcareous earth, like the calcareous earth in its natural state. These several particulars occasioned lime-water to be considered as a surprising unaccountable fluid. When fresh drawn from the lime, it has a pungent, acrid, alkaline taste, and several other qualities, as if it contained an alkaline salt. And it retains these qualities if it be shut up in close vessels; but if exposed to the air, it becomes quite insipid. And yet we can observe no cause of this change, but the separation or rejection of an earthy matter from it, which is also perfectly insipid, and which cannot again be dissolved.

There remains to be mentioned one other property only of lime, and it is one of its most useful properties; I mean that of making good MORTAR, when it is skilfully mixed with sand and water. The qualities of *good mortar* are, to adhere readily to stones or other solid bodies; to cement them together; and to acquire, by time, a stony hardness. These qualities, in such a mixture, have been thought the more surprising, for these reasons, that lime and water without sand

has not all the qualities of good mortar, and that nothing is ſo little diſpoſed to cohere as ſand by itſelf.

After all, however, the effect of the ſand in giving coheſion and hardneſs to the lime and water has been exaggerated. And Mr. Macquer errs a little from the truth, when he ſays that lime and water without ſand do not concrete in the leaſt.

If we give to a paſte of lime and water the form of a ſmall ball, and allow it time enough, that it may dry ſlowly, it will contract its ſize, and become very hard,—harder, I believe, than if ſand had been added. But that is not the way in which lime mortar is uſed. It is not made into balls or other maſſes that are to dry and harden without being connected with other matter; it is employed for cementing ſtones or bricks together, and for plaſtering walls and other ſuch parts of buildings. And, if it were made up ſo as to be liable to contract much in drying, the conſequence would be, that it muſt neceſſarily ſeparate from thoſe bodies to which it is applied, and which cannot contract along with it; or, if continued adhering to them, it muſt ſplit and divide itſelf into innumerable ſmall parts, and ſo become quite ſhattered and uſeleſs. The reaſon why lime alone, when made into a paſte with water, contracts ſo much, is the great quantity of water which ſuch a paſte contains; for a good quantity of water is required to make ſlaked lime into a ſoft paſte. But this contraction and its conſequences are prevented almoſt entirely by the addition of ſand to the lime.

Some ſkill, however, is required to add the ſand in the moſt proper manner. If too much be added, the mortar will not be very hard and firm when it dries. The ſand will give it an openneſs of texture, which both diminiſhes the coheſion of its parts, and admits water too readily into its pores, and expoſes it to the effects of froſt.

Some time ago, a French engineer, Loriot, propoſed a contrivance, which he aſſerted to be a great improvement in the compoſition of

lime-mortar for many purpoſes, and by the uſe of which leſs ſand was neceſſary to prevent its contraction. He made common mortar with the uſual proportion of ſand, but with a little more water than ordinary, ſo as to be almoſt fluid; and juſt before it is uſed, he added to it one-fourth or one-third of quicklime, not ſlaked, but reduced to powder mechanically. When quicklime is thus mixed with a good deal of cold water, it does not ſlake ſo ſuddenly as when no more water is uſed than is neceſſary to ſlake it. The quicklime put in does not ſwell and ſlake until the mortar is uſed, and put in its place. The powder of the quicklime, then ſlaking throughout the whole of the mortar, abſorbs and conſolidates a part of the water which it contains; and the mortar becomes hard and dry remarkably ſoon, and without contracting. And when the reſt of the humidity is evaporated, it acquires a degree of hardneſs and compactneſs far ſuperior to that of ordinary mortar. It is impenetrable by water. Vaſes of it filled with water do not imbibe a ſenſible quantity. The hardneſs and ſtrength of this mortar, is undoubtedly owing to its denſity and more perfect ſetting. Mr. Loriot was of opinion that the Romans made their mortar in ſome ſuch manner. Lime mortar ſets in time, if left at reſt. This ſetting is ſomewhat analogous to the concretion of ſalt and water in the act of cryſtallization. Mortar will ſet again and again, after kneading or beating up, but more weakly than before. Loriot's mortar, therefore, muſt ſet the moſt ſtrongly of all, becauſe it is not afterwards diſturbed.

Since Loriot, Dr. Higgins of London publiſhed a little tract on this ſubject, containing a deſcription of a great number of experiments, made to diſcover the beſt compoſitions for making mortar or lime cements of different kinds. His experiments agree in ſhewing that the hardneſs and ſtrength which mortar or lime cements acquire depend very much on the freſhneſs and activity of the lime employed. And, in his receipt for the beſt compoſition, he inſiſts particularly on a method of uſing the whole lime in its moſt active poſſible ſtate, ſo as it

may be expoſed to the air as little as poſſible, after being burnt and ſlaked. And he alſo found that much advantage was gained by uſing ſands of different ſizes mixed together, and even a ſmall addition of ſome other ingredients ſtill finer than the fineſt ſand. The particulars of all this are in his pamphlet, which I think judicious.

There is a way of making a lime-mortar or cement, the concretion and induration of which does not depend on its being dried. It is found to concrete and become hard and very durable, even under water, and is therefore uſed in buildings or works that ſtand in water, or are very much expoſed to be waſhed by it; and ſuch mortar is named water-mortar. Mr. Smeaton having had occaſion to uſe this mortar in building a moſt uſeful and important light-houſe, which ſtands on a low narrow rock in the mouth of the Channel, where it is often expoſed to the utmoſt fury of the waves, exerted all his ingenuity to make the building durable; and among many other points, made a number of experiments to aſcertain the beſt compoſition for water-mortar. And he was ſo accurate and induſtrious in his inveſtigation of it, that he is the beſt author to be conſulted on this ſubject. The detail of his experiments is given in the account he publiſhed of the building of that light-houſe, which was a moſt arduous work.

I have now proceeded ſo far in the hiſtory of the calcareous earth, as to have related the principal facts upon which were founded the firſt attempts to explain this ſubject, and to account for the difference between the earth in its natural ſtate, and in the ſtate of quicklime.

In general, thoſe who attempted to give an explication applicable to the whole, or to the greater part of this ſubject, entertained a notion, or rather formed a ſuppoſition, that the calcareous earth, when burnt to quicklime, receives ſome ſubtile and active principle, communicated to it by the fire or heat; that from this principle it derives its acrimony, activity, and ſolubility in water. They imagined that lime-water is produced by diſſolving ſuch a part of the lime as has the largeſt proportion of this principle combined with it, and that this principle

evaporates from the lime or lime-water expoſed to the air. Further, ſome ſuppoſed that this principle is attracted from the lime by alkaline ſalts, and that thus are produced the cauſtic alkalis. The greater number, however, ſeem rather to have conſidered theſe as compounds of the alkali and the quicklime in ſubſtance, or the more acrid part of the quicklime. But neither has the exiſtence of this active principle ever been demonſtrated, nor is the ſuppoſition of its combining with lime conſiſtent with many capital facts which are known to all. Indeed it is inconſiſtent with our general experience in chemiſtry. When limeſtone is burnt to quicklime in the fire, inſtead of receiving any addition, it ſuffers, on the contrary, a very conſiderable loſs: And the alkali is alſo diminiſhed in weight when rendered active by the quicklime. Moreover, we generally find, that the combination purely chemical, of the moſt active ſubſtances, generally diminiſhes their activity. It is thus that neutral ſalts are leſs active than their ingredients.

Other theories have been attempted, as I ſaid, chiefly to explain ſome parts of the ſubject. Such was Dr. Stahl's opinion. He was one of thoſe who believed ſalts to be compounds of earth and water; and he ſuppoſed ſlaked lime to be a ſort of ſalt haſtily and imperfectly formed; and therefore liable to be eaſily decompounded again into its conſtituent parts,—calcareous earth and water.

Mr. Macquer again, in order to explain ſome particular phenomena, ſuppoſed that the calcareous earth acquires a ſmall quantity of ſome acid principle in the fire, juſt enough to give it ſolubility in water, but in too ſmall quantity to ſaturate it; and therefore lime is ſtill alkaline. By this ſuppoſition he endeavours to explain the action of lime and tartar on one another; but at the time when he wrote, the nature of tartar was but imperfectly known, and ill underſtood. And neither his theory nor Dr. Stahl's are at all ſatisfactory when cloſely examined. You may ſee an account and examination of

thoſe theories, in the ſecond edition of the Engliſh tranſlation of Macquer's Dictionary, under the article *Cauſticity*.

Upon the whole, the chemiſts had been, at that time, but little attentive to the variety of earthy bodies, and had but an indiſtinct knowledge of any alkaline earth, except the calcareous.

They only knew that there were two or three earths beſide the calcareous; and they knew ſome ſaline compounds which held earths combined with acids; but they had not turned their attention to them, ſo as to examine by experiments how they were diſtinguiſhed from one another. They ſuppoſed them to be all more or leſs ſimilar to the calcareous, or to have a great deal of affinity with it, if they be not the ſame thing.

Dr. Hoffmann was the firſt who gave diſtinct notice of an alkaline earth, which he ſhewed to be different from the calcareous. It was called *Magneſia*. When I firſt began to make chemical experiments, I had the curioſity to examine more carefully this earth indicated by Hoffmann. I made a number of experiments to learn its properties, and how it was diſtinguiſhed from the calcareous and ſome other earths. The reſult of theſe experiments ſuggeſted to me, ſome time after, an explication of the nature of lime, and of its effects on the alkaline ſalts, and engaged me in an inquiry, by which a clear light was thrown on this ſubject, and on many other important parts of the ſcience of chemiſtry.

I propoſe, therefore, to give an account of that inquiry. It is a long ſtory. But when I began to give theſe lectures, and for a long time after, I was in ſome meaſure under the neceſſity of following this method, giving, at full length, the inveſtigation of the ſubject of quicklime, and the foundation of the opinion and ſyſtem which I formed upon that ſubject; for this reaſon, that it was not generally underſtood and approved of by the chemiſts abroad. Some choſe to doubt, or explain in a different way, the proofs which I had adduced; and they adhered to their old opinions. Others ſet up, or ſupported and extolled

another new ſyſtem, which was directly contrary to mine. So long as the opinion of a number of reputable chemiſts was unfavourable to my views of the ſubject, I thought it became me to ſhew the grounds of my opinions; and to leave thoſe to whom I addreſſed myſelf at liberty to judge for themſelves. Of late, however, moſt foreign chemiſts and philoſophers agree on this ſubject with me.

But I think it is ſtill worth your while to hear a hiſtory of the inveſtigation. The ſame facts and doctrines, when delivered in a dogmatic or didactic manner, do not make ſuch an impreſſion as when made the ſubjects of hiſtorical narration. The mind is then led through the moſt natural chain of ideas; it being that which took place in the mind of the perſon who followed out the inveſtigation.

I ſaid juſt now, that a diſſertation or eſſay of Dr. Hoffmann's, on an earth called magneſia, occaſioned the beginning of the inquiry, the hiſtory of which I am going to give you. But I was peculiarly excited to it by the then recent diſcoveries of the power of lime-water to give relief in caſes of the ſtone and gravel, in which it was ſuppoſed to act by diſſolving thoſe concretions, and expelling them out of the body. Dr. Whytt and Dr. Alſton, profeſſors in this univerſity, were then engaged in a diſpute on this ſubject. They both believed that it had efficacy; but Dr. Whytt imagined that he had diſcovered that the lime-water of oyſter-ſhell lime had more power as a ſolvent, than the lime-water of common ſtone lime. I therefore conceived hopes that, by trying a greater variety of the alkaline earths, ſome kinds might be found ſtill more different by their qualities from the common kind; and perhaps yielding a lime-water ſtill more powerful than that of oyſter-ſhell lime.

I therefore began by examining the alkaline earth which Hoffmann had mentioned or deſcribed; and for the preparation of which there was a proceſs given in our pharmacopœia.

SPECIES II.—MAGNESIA.

We learn from Dr. Hoffmann, that it was a white earthy powder, which had gained reputation as a ſecret remedy, under the name of the POWDER OF COUNT PALMA, or MAGNESIA ALBA. The Doctor having learned the manner of preparing it, which he deſcribes, made ſeveral trials to aſſure himſelf of its medical virtues, and to acquire ſome knowledge of its nature in other reſpects. And he reports that it is an alkaline or abſorbent earth, which effervesces with all the acids, and neutraliſes them; that it is, therefore, proper for neutraliſing acids in the ſtomach, with this additional good quality, by which it is diſtinguiſhed from the calcareous earth commonly employed at that time by phyſicians, that the magneſia has purgative or laxative powers, and therefore clears the bowels from the undigeſted matter which had produced the acid. And he ſuppoſed that the purgative power was a quality of the compound of the magneſia and acid after they were united together in the ſtomach.

The ſubjects from which Dr. Hoffmann prepared this earth, were ſome ſaline compounds, in which it is combined with acids; and theſe ſaline compounds are obtained in preparing nitre and common ſalt. He firſt made uſe of that which is got in preparing nitre, or in extracting the nitre from nitrous earths and compoſts. It is called the MOTHER LEY OF NITRE *.

But, afterwards, having learned, that, in preparing common ſalt from the waters that contain it, a ſimilar liquor is obtained, he made uſe of this alſo in ſome of his proceſſes for preparing magneſia. This

* *Moder* is the German word for ſcum, mud, or dregs, which ſeparates from vinegar, ale, or other liquids, by careleſs keeping. This term is ſtill in uſe in the northern parts of theſe iſlands, and the liquor is ſaid to *mother*. The French tranſlate it ignorantly *eau mere*. EDITOR.

bitter ſaline liquor, produced in manufacturing common ſalt, is well known to our ſalt boilers who prepare ſalt from ſea-water: And they call it *Bittern* in England,—in this country commonly *Oil of Salt*.

Dr. Hoffmann deſcribed two ways of obtaining this earth from theſe ſaline liquors. The firſt was by evaporating the ſaline liquor to dryneſs, and then expoſing the dry matter to a red heat in a crucible; by which heat ſome acid vapours were expelled, and the earth remained in the crucible. The ſecond was by adding to the ſaline liquor a ſolution of an alkaline ſalt, which immediately precipitated the earth, by uniting with the acid with which this earth was combined. And he prefers this proceſs to the other.

In this country, as we cannot procure any of the nitrous liquor, we have always prepared our magneſia from the *bittern* of common ſalt, or of ſea water. Or, which is the ſame, we prepare it from the ſaline compound which is got from the bittern by cryſtallization.

The ſaline compound has been long uſed in the practice of medicine, under the name of *Sal catharticus amarus*, the bitter purging ſalt. It was firſt obtained from the waters of ſome purging mineral ſprings at Epſom, in Surrey, and ſold at an high price, on account of the ſmall quantity of it which thoſe waters contained. But afterwards, the manufacturers of common ſalt, finding they could get it in plenty from the bittern of ſea water, and very cheap, prepared large quantities of it, at Lymington eſpecially, and exported it to the Continent, where great quantities were ſold.

The appearance of it, as commonly prepared from the bittern, is that of ſmall priſmatic or columnar cryſtals. It is rather more purgative than Glauber's ſalt, or ſulphat of ſoda, and of a bitteriſh, and vaſtly more diſagreeable taſte. Theſe cryſtals contain about one half of their weight of water, and therefore readily undergo the watery fuſion when ſuddenly heated. The reſt of their ſubſtance is a compound of the ſulphuric acid and an alkaline earth, which becomes evident by the action of an alkali on this ſalt. The alkaline earth,

which is the magneſia, is precipitated: And, by the ſame experiment, we learn that the acid with which it was combined is the ſulphuric. It forms, with the vegetable alkali added, a ſulphat of potaſh. The Epſom ſalt is, therefore, a ſulphat of magneſia.

This ſaline compound, being cryſtallized with a little more care than is commonly employed in manufacturing it, concretes into much larger cryſtals, which, as they reſemble and even excel Glauber's ſalt by their purgative quality, have alſo a good deal of reſemblance to it in their appearance. This became known to the manufacturers, who ſoon cryſtallized large quantities of it in this manner, and ſold it for Glauber's ſalt for ſome time. But the fraud was detected, and Glauber's ſalt has been ſold ſo cheap ſince that time, that it is not worth while to attempt ſuch a fraud, eſpecially ſince the method for diſtinguiſhing the one of theſe ſalts from the other is generally known. We need only to diſſolve a little of the ſalt in water, and add an alkali. The ſolution of the ſulphat of ſoda remains tranſparent. The other becomes turbid and thick by the precipitation of the magneſia.

By not having knowledge of this diſtinction, Mr. Pott, of the Berlin Academy, maintained a diſpute with Monſ. Du Hamel, of the Royal Academy of Sciences, about the alkaline baſis of common ſalt. Mr. Pott aſſerted that common ſalt contained an earth for its baſis. Mr. Du Hamel demonſtrated by experiments, that it contains an alkaline ſalt. Pott had drawn his concluſions from experiments made with the ſulphat of magneſia, which was ſold at that time in Germany as Glauber's ſalt; and he did not ſuſpect that it was any thing elſe. But, as genuine Glauber's ſalt is prepared from common ſalt and ſulphuric acid, it muſt neceſſarily have the ſame alkaline baſis as common ſalt. And finding that the ſalt which paſſed for Glauber's ſalt in Germany had an earth for its baſis, he concluded that common ſalt muſt contain the ſame earth.

The proceſs I uſed for preparing magneſia for my experiments,

was, that we have now in the Edinburgh Pharmacopœia, or much the ſame. I diſſolved in water ſeparately equal quantities of Epſom ſalt, (ſulphat of magneſia) and of potaſh, ſuch as is commonly ſold under the name of pearl-aſh. The Epſom ſalt muſt be diſſolved in twice its weight of the pureſt water, and an equal quantity of dry pearl-aſhes muſt be diſſolved in four or five times its weight of pure water. Each of theſe ſolutions muſt be carefully purified from all admixture or foulneſs. The alkali may be purified by ſubſidence and decantation. It is adviſeable to clarify the ſolution of Epſom ſalt with the white of egg, violently agitated with it when juſt hot enough to coagulate the egg. This produces a fine net-work, which will entangle every thing that is not chemically diſſolved, and the clear ſaline ſolution will then drain ſlowly through a linen cloth.

Equal quantities of the two ſalts having been thus diſſolved, the clarified ſolutions muſt be mixed together by violent agitation, in order that the ſalts may act quickly on each other, and the decompoſition be as perfect as poſſible. This muſt be further promoted by making the mixture juſt boil over a briſk fire.

Now, add to the mixture four times its bulk of boiling hot water, and again agitate briſkly. Let it now ſtand to ſettle. The magneſia is ſcattered over the whole liquor in a moſt impalpable powder, and will ſubſide with extreme ſloweneſs. When ſettled, decant off the clear liquor, and again pour on it the ſame quantity of cold water, and, when it has completely ſettled, again decant the clear liquor. This edulcoration muſt be repeated ten or twelve times before the magneſia can be cleared of the vitriolated tartar, formed by the alkali and the ſulphuric acid of the Epſom ſalt, which, you know, requires a prodigious quantity of water for its ſolution, eſpecially when cold ;— and in theſe ablutions it is found that hot water occaſions a much longer ſuſpenſion of the magneſia. But theſe repeated effuſions will effectually clear it of all ſaline admixture, leaving the magneſia pure, and in a fit ſtate for philoſophical examination. Having decanted off

the taſteleſs water for the laſt time, ſtrain the ſediment through a linen cloth, uſing gentle compreſſion at laſt,—for very little of the powder will come through. N. B. We ſhall never ſucceed by uſing the finer filtering papers. For, although magneſia is a fine hard powder, yet, while wet, it has more the appearance, the feel, and even the tranſparency, of a jelly *.

There are ſeveral niceties in this proceſs, which ſeem ſomewhat capricious, but are abundantly plain when we attend to the properties of the ſubſtances employed. The vitriolated tartar, being of difficult ſolution, impedes by its very formation the progreſs of the decompoſition; therefore boiling briſkly is abſolutely neceſſary. Alſo, the magneſia has a tendency to a peculiar mode of cryſtallization in little round grains formed, like zeolyte, of ſpiculæ diverging from a centre. They are hard, and would be very inconvenient for medical preparations. When a very minute quantity of the two ſalts is diſſolved in a great deal of water, and allowed to reſt without diſturbance, the particles have room and time to aſſume this arrangement very regularly. Therefore, we muſt prevent this by making our firſt liquors pretty rich in the ſalts, and this, with the agitation and boiling, immediately deſtroys this regular formation of cryſtals, and cauſes the whole to become a fine impalpable powder. I find that a quart of water to a pound of Epſom ſalt, and three quarts to a pound of dry pearl-aſhes, are a very good degree of ſtrength for the firſt ſolutions. The gelatinous appearance, when wet, ariſes from a ſpongy adheſion of a great quantity of the water, and when this is evaporated to dryneſs, the maſs is an exceedingly light and ſpongy ſubſtance,—and this extreme lightneſs is one of the beſt marks of its goodneſs. Mr.

* This tranſparency is unfortunate for the painters; for magneſia would otherwiſe give a moſt dazzling white, ſuperior to any they poſſeſs, and which would not change its colour, as the preparations of white lead do. But when ground with oil, it has hardly any colour, forming an almoſt tranſparent varniſh. It will do perfectly well, however, in water colours, becauſe it regains its brilliancy when perfectly dry.

EDITOR.

Henry of Mancheſter thinks that in this proceſs too little water is uſed, ſaying that theſe gritty particles require a vaſt deal of water to diſſolve them. But this is a miſtake,—no quantity whatever of pure water will diſſolve them; and if the firſt liquors are not too much diluted, and the mixture be well agitated at the firſt, theſe gritty particles will not be formed.

My preſcription of equal quantities of the two ſalts, as proper for decompounding the Epſom ſalt, is founded on an experiment by which I diſcovered that it requires 100 grains of dry alkali to ſaturate the acid ſaturated by 30 grains of calcined magneſia.

Having thus procured a magneſia, of the purity of which I am certain, I was anxious to examine it as a medicine. I made a ſalt by diſſolving it in vinegar, thinking this acid the moſt nearly analogous to that which is formed by vegetable matter, imperfectly digeſted in weak ſtomachs. Two drachms of this powder proved a good purge for an adult, and half an ounce a very briſk purge, but both operated gently and without any ſpaſm or ſenſible inconvenience. The taſte was in a moderate degree nauſeous.

Let us now attend to the chemical relations of this new ſubſtance; and, firſt, with regard to the acids.

1*ſt*, It effervesces with all the acids, and neutraliſes them; and forms with them compounds remarkably different from thoſe formed by the calcareous earth. With the ſulphuric acid, for example, it forms a compound eaſily ſoluble in water;—with the nitric acid a compound ſoluble and cryſtallizable;—with the muriatic acid a deliqueſcent compound, but which differs from the calcareous compound with this acid, by being ſubject to decompoſition, or ſeparation of its acid, or of the greater part, by the action of heat alone. Its compound with the acetous acid has been already deſcribed.

2*dly*, Magneſia, prepared in the way now deſcribed, ſeparates the calcareous earth from acids. When a little uncalcined magneſia is put into a ſolution of the muriat of lime, and the mixture promoted by

agitation, and allowed to ſettle, we have a powder lying at the bottom, which is not diſtinguiſhable at firſt from the magneſia that we put in. But when it is dried and edulcorated, we find it to be a calcareous earth, for it burns to a true quicklime, wholly ſoluble in water. If we have added enough of magneſia, and not too much, we ſhall find that, after having ſeparated the powder now ſpoken of, if we then pour a little ſulphuric acid into this ſolution, we ſhall obſerve no precipitation. Now we know that the ſulphuric acid, when added to the muriat of lime, forms a ſelenite hardly ſoluble in water. Again, if, inſtead of the ſulphuric acid we put a ſolution of Glauber's ſalt into the ſaline liquor we are now conſidering, we ſhall obtain an Epſom ſalt and common ſalt.

3dly, It produces a very remarkable effect on lime or lime-water. In the firſt experiments by which this was diſcovered, I added ſome magneſia to a muddy mixture of lime and water. The lime was rendered inſoluble. In a ſecond experiment I added the magneſia to lime already diſſolved; that is, to lime-water. After long digeſtion and frequent agitation, the water was rendered perfectly taſteleſs, and the powder at the bottom was a mixture of magneſia and crude calcareous earth.

I was induced to try theſe experiments with lime and lime-water by the event of the preceding experiment, which made me imagine it was allied to the alkalis.

4thly, When expoſed to the action of fire, it does not become a quicklime. Some magneſia, which had been expoſed to a ſtrong heat, was tried with water, to learn whether it would ſlake like lime, or form a lime-water. I alſo laid a little of it on my tongue, to learn whether it had acquired any degree of acrimony. But in none of theſe trials did it ſhew the qualities of lime. It neither ſlaked or ſhewed any attraction for water like quicklime, nor formed a lime-water; nor was it ſenſibly acrid when laid on the tongue. I learned, however, that in ſome of its qualities it is conſiderably affected and chan-

ged by the fire; and I called it calcined or burnt magnesia. The changes induced on it by the action of the fire, when a good red heat has been applied to it for some hours in a crucible, are these:

1*st*, We find that it is much diminished in bulk.

2*dly*, We also find that its weight is very considerably diminished, viz. by more than $\frac{1}{2}$;—or, by $\frac{7}{12}$ths, 12 parts are reduced to 5.

3*dly*, When we try how the magnesia, in this diminished state, dissolves in acids, we find it can be dissolved without the least effervescence. When lime is thrown into strong and brown sulphuric acid, there is sometimes a violent heat produced (even flashes of flame) which makes the water boil; but this happens only when the acid is applied too strong; and it is quite different from the effervescence which appears in dissolving magnesia in its ordinary state. And if we dilute the acid properly before we apply it to the calcined magnesia, there is no ebullition whatever, but only a moderate degree of heat produced.

This suggested an improvement of magnesia as a medicine for some cases and constitutions. Hoffmann remarks that some of his patients complained of the magnesia, saying that it raised wind in their bowels; and this he imputes to its effervescing quality. But by thus calcining it, we deprive it of this quality, although it unites with acids as effectually as before; for by dissolving the calcined magnesia in the different acids, I learned that it neutralises the acids, and produces compounds entirely similar to those produced by the magnesia before it has been calcined. The use of calcined magnesia in medicine requires, however, some caution and attention: For magnesia, in the shops, is not always perfectly pure. Some of it contains a portion of calcareous earth; and if such magnesia is calcined, we shall have a portion of quicklime in it; which is not safe for internal use. The calcareous earth which is often found in common magnesia, proceeds either from a sulphat of lime, which is often contained, in small quantity, in the Epsom salt, or from a sulphat and a

muriat of lime contained in the water with which the magneſia was waſhed, if this was a hard or a bad water. It very rarely happens that any troubleſome degree of flatulence is produced by common magneſia; and if there ſhould, the addition of ſome aromatic will be a ſufficient antidote.

4*thly*, A fourth peculiarity of the calcined magneſia was, that it did not ſeparate the calcareous earth from acids. And a

5*th*, That it did not precipitate the lime from the lime-water.

The reſult of theſe trials prompted me to make further experiments, to learn in what manner the fire produced theſe changes in the magneſia, and what was the nature of that matter which was ſeparated from it by heat in ſuch great quantity, and by the loſs of which it was ſo much reduced in its bulk and weight.

I therefore put a quantity of magneſia into a glaſs retort, and joined a receiver to the retort with common lute made of ſand and clay. I then placed the retort in a ſand-pot, which was very gradually heated until the bottom of the pot began to be ignited. The receiver was kept cool, to promote the condenſation of any volatile matter that might ariſe from the magneſia; but I obtained only a very ſmall quantity of watery fluid, which contained a ſmall portion, ſcarcely perceptible, of volatile alkaline matter. The magneſia which remained in the retort had loſt a great deal of its weight, (though not ſo much as when it is heated to a good red heat in a crucible); yet the loſs it had ſuffered was equal to more than ſix or ſeven times the weight of the ſmall portion of water condenſed in the receiver. This appeared at firſt an unaccountable fact; but it made me recollect ſome of Dr. Hales's experiments, deſcribed in the eſſay to which he gave the title of Analyſis of the Air, and in other parts of his works.

Mr. Boyle had before made experiments, in which he extracted air from different ſubſtances by the uſe of the air-pump, and by other means. But Dr. Hales puſhed ſuch experiments a great deal farther. He expelled, by the action of heat, from a variety of different ſub-

ſtances, large quantities of elaſtic incondenſible fluids, which he conſidered as different kinds of air, or as air in different ſtates, which had been concealed in theſe bodies, united with their other ingredients in a denſe and ſolid form. Chemiſts have diſtinguiſhed this claſs of elaſtic fluids from atmoſpherical air, by the term GAS, a German word uſed to expreſs the eruption from fermentations *(garung)* of every kind. *(See Note 2. at the end of the Volume.)*

The apparatus he uſed in many of theſe experiments was very ſimple, conſiſting of a gun-barrel cloſed up at the breech, and bent into a ſwan neck. The ſubſtance from which the gas is to be expelled by fire, is put into the barrel, and this end is put into the fire. The other end is dipped in a tub of water, and a jar filled with water is inverted over the mouth of the barrel. The preſſure of the atmoſphere ſupports the water in the jar. The gas expelled from the gun-barrel riſes through this water, diſplaces ſome of it from the jar, and occupies the upper part of it *.

By ſuch experiments, and by others, Dr. Hales got great quantities of air, or permanently elaſtic fluids, from a great number of vegetable, animal, and foſſil ſubſtances. And this explained to the chemiſts ſome facts which often occurred in their diſtillations, and which they had not been able before to underſtand, viz. loſs of weight, and the burſting of their diſtilling apparatus, in ſpite of all attempts to promote condenſation. Obtaining a vaſt deal of air in the ſame apparatus without red heat, from peaſe, and other fermentable ſubſtances, gave ſome knowledge of what happens in fermentation.

As what had happened in the laſt experiment with magneſia appeared to be very ſimilar, I began to ſuſpect that the loſs of weight which it ſuffered in the fire was occaſioned, in the ſame manner, by the loſs of a quantity of elaſtic aërial matter, or air, which had eſcaped through the lute. And this ſuppoſition appeared the more

* The ſame apparatus was employed by Mayhow in 1674.

EDITOR.

probable, as it was very conſiſtent with one of the qualities of burnt magneſia; I mean its uniting with acids without effervescence. For I began to ſuſpect that the effervescence of the common magneſia proceeded from air which it contains, and which is expelled by the ſuperior attraction of the acid; and that the reaſon why burnt magneſia did not effervesce was, that it did not contain this air, the air having been expelled from it by the action of heat.

Another fact which ſupported the ſame opinion, was the ſucceſs of an experiment, in which I contrived to reſtore this air again, if poſſible, to the calcined magneſia.

The contrivance or plan of this experiment was ſuggeſted by conſidering in what manner the magneſia had got this air at the firſt. It could not have it while it was joined with the ſulphuric acid in Epſom ſalt. The effervescence of magneſia with acids, ſhews that it cannot be joined with an acid and this air at the ſame time. It muſt therefore have received it from the alkali which was employed to precipitate it from the acid. This appeared the more probable, from recollecting that Dr. Hales had long before extracted much air from alkaline ſalts. By heating ſome alkali of tartar in his iron retort or gun-barrel, he extracted from it 224 times its bulk of air. In other experiments, he got great quantities of air, by adding different acids to ſolutions of alkalis.

I therefore ſuppoſed that magneſia receives air from the alkali employed to precipitate it at firſt; that we can expel this air from it by the action of fire; but that it might perhaps be reſtored by diſſolving the burnt magneſia in an acid, and precipitating again by the addition of an alkaline ſalt.

To make trial of this, I took 120 grains of common magneſia. I burnt it in a crucible with a ſufficient heat, by which it loſt 70 grains of its weight. This magneſia, thus calcined, was diſſolved in a ſufficient quantity of diluted ſulphuric acid, in which it diſſolved without effervescence, and it was again precipitated by adding a clear and

warm ſolution of a common fixed alkali, which was boiled with it a little in the uſual way; and the precipitate was waſhed in the uſual manner. After being carefully dried with a gentle heat, it was found to have regained the whole weight which it had loſt in the fire, except a mere trifle. It alſo effervеſced with acids as violently as common magneſia. It ſeparated the calcareous earth from acids, and it made the lime ſeparate from lime-water. Thus it was reſtored to the ſtate of common magneſia in every reſpect. It was juſt the ſame as if it never had been calcined.

The event of this experiment, therefore, confirmed me in the perſuaſion, that magneſia receives a quantity of air from the alkali employed in preparing it; and that the precipitation of magneſia from Epſom ſalt is not a caſe of ſingle, but of double elective attraction.

This became ſtill more evident, by conſidering attentively what happens in precipitating magneſia; for the alkali, in precipitating it, forms with the acid a compound ſalt, which is preciſely the ſame in quantity and quality, as if the ſame alkali had been ſaturated with a pure acid. When an alkali is ſaturated with a pure acid, we ſee plainly that the air of the alkali is expelled. The effervеſcence ſhews this, and Dr. Hales's experiments. And the compound ſalt produced is a compound of the acid with the alkali deprived of its air. But as the compound ſalt produced in precipitating magneſia is preciſely ſimilar, in quantity and quality, to a compound ſalt produced from the ſame quantity of alkali and a pure acid, the alkali of it cannot have retained its air. This air muſt have been expelled by the acid, and yet this expulſion of the air is not apparent by any effervеſcence. But as the air is actually found in the magneſia, this accounts for the non-appearance of effervеſcence, and ſhews that in the precipitation of magneſia there is a double elective attraction or double exchange. The alkali unites with the acid, ſeparating the magneſia, which in the ſame inſtant unites with the air as it quits the alkali. We muſt therefore conclude that the ſum of the forces which tend to unite the

alkali with the acid, and the magneſia with the air, is greater than the ſum of the forces that tend to unite the magneſia with the acid and the alkali with the air.

Thus, I found reaſon to ſet aſide the common opinion then entertained of the nature of the efferveſcence of acids with alkalis and alkaline ſubſtances. It was generally ſuppoſed to be a conſequence or effect of the violent ſhock of the acid and alkaline particles,—but it now appeared to be a ſeparation of a quantity of air which is preſent in alkalis, but which is expelled by the ſuperior attraction which the acid has for the alkali.

When I now reflected on the great loſs of weight which magneſia ſuffered in being calcined, it occurred that the quantity of air which it contains muſt be very conſiderable, and that it and the other alkaline ſubſtances, muſt loſe a proportional part of their weight during their efferveſcence with acids,—ſince we have reaſon to conclude that this efferveſcence is nothing elſe but a ſeparation and diſcharge of this air.

This idea led me to examine what loſs of weight magneſia, or the common fixed alkali, would ſuffer by their efferveſcence with a pure acid, for which purpoſe I made the following experiments:

Into a diluted acid contained in a flaſk or phial, put a little alkaline ſalt, or chalk, or magneſia, and immediately ſtop the mouth with a cork, through which there paſſes a tube bent into a ſwan-neck. The other end of the tube is introduced (in Dr. Hales's manner) into an inverted glaſs jar filled with water, and ſtanding in a tub of water. You will obſerve the efferveſcence, and the elaſtic bubbles riſing copiouſly through the water to the top, where they collect, driving the water out of the jar.

Thus it is manifeſt that it is not a temporary vapour, but a permanently elaſtic fluid, which eſcapes in the efferveſcence, not condenſible by cold.

Mr. Homberg, therefore, was led into an error in the experiments

which he made and publiſhed in the memoirs of the Academy, to determine the ſtrength of the different acids, and the proportion of the acid to the alkali in the compound ſalts. He ſaturated equal quantities of an alkali with each, and concluded that the weight gained by the alkali, when perfectly dried, was the quantity of ſolid ſalt contained in that part of the acid which had completed the ſaturation. But we now ſee that he ought to have added the weight of all the air that is loſt by the alkali.

We can alſo now perceive the reaſon why common and burnt magneſia, which differ by ſeveral properties, agree in forming the ſame ſalts with the different acids; for, ſince the different qualities of the magneſia in theſe two ſtates proceed from the preſence or abſence of the air, it muſt happen that when magneſia, in its ordinary ſtate, is diſſolved in an acid, the air is expelled,—the compound produced muſt therefore be the ſame as if we had diſſolved burnt magneſia, or magneſia previouſly deprived of its air by fire.

The only other experiments which I firſt publiſhed in my inaugural diſſertation on magneſia, were a few more on the earth of alum, and on the aſhes of animal bones, which were at that time employed in medicine as an alkaline earth. I ſatisfied myſelf that neither of them acquired the qualities of quicklime in a ſtrong fire; and that was one principal object of my inquiry. More light has been thrown upon both theſe earthy ſubſtances ſince that time by eminent chemiſts in Germany and Sweden; but of this we ſhall give further notice ſoon.

Such were the experiments which I then made to inveſtigate the nature of magneſia. And from theſe you will perceive that this alkaline earth is very diſtinct from the calcareous. I need not add any thing further with regard to it at preſent; but ſhall take ſome notice of the different ſtates in which we find it in nature.

It is produced by nature in great quantity. The ſulphat of magneſia is contained in conſiderable quantity in the waters of the ſea; and occurs alſo in many ſpring waters, in which it has been often

miſtaken for Glauber's ſalt. And ſometimes waters that contain it, when they happen to be expoſed in circumſtances proper for evaporation, leave this ſalt behind in a concreted or cryſtallized form. Such is this ſpecimen which I was told came from a coal-pit in England. And I am perſuaded, that the ſalt called Glauber's ſalt, which is ſaid to be found ſolid in Siberia in ſuch great quantities as to ſupply the conſumption of the whole empire of Ruſſia, is not in truth a Glauber's ſalt, or ſulphat of ſoda, but a ſulphat of magneſia. My reaſon for this opinion is, that in Ruſſia they do not know the diſtinction between this ſaline compound and ſulphat of ſoda. Mr. Model, the Empreſs's apothecary, in one of his eſſays, mentions, as a well known property of Glauber's ſalt, that when we diſſolve it in water, and add a ſolution of the fixed alkali, there is a plentiful precipitation of earth, which certainly happens with Epſom ſalt only, but not with Glauber's ſalt. And there are other paſſages in his eſſays, which ſhew plainly, that what they called Glauber's ſalt in Ruſſia, was no other than this ſalt.

We may further remark with reſpect to the natural waters which contain ſome of this ſalt, that they alſo often contain a ſmall quantity of a muriat of magneſia. There is always a quantity of it contained in ſea water.

But theſe are not the only ſtates in which magneſia is found. Mr. Margraaf of Berlin made great additions to the natural hiſtory of this earth, by diſcovering that it exiſts alſo ſeparate from any acid, and ſometimes pretty pure. There is a ſet of earthy or ſtony ſubſtances, concerning the claſſing of which, foſſiliſts were a long time undecided and diſagreed. Moſt ranked them among the clays, and Cronſtedt among the reſt. They have been known by the names ſteatites, lapis ſerpentinus, lapis nephriticus, and lapis ollaris. In the pureſt, the texture is cloſe and ſemitranſparent. In ſome ſpecies, it is ſomewhat plated or ſcaly. In general they are ſoft like ſoap or ſuet; ſo ſoft as to be cut or turned. It hardens in the fire without melting. Hence ſome ſpecies are turned into veſſels. This is the lapis ollaris. Inve-

rary Houſe is built of an impure ſpecies of it. Mr. Margraaf firſt ſhewed that all theſe contain more or leſs of magneſia, cloſely combined with ſome other earthy ſubſtances, and often with much iron, by which they are tinged with the green colour, more or leſs deep, that appears in many of them.

Mr. Margraaf alſo found that magneſia is an ingredient in the compoſition of the flexible ſtony ſubſtances, which we ſhall hereafter deſcribe. And Mr. Lewis got ſome of it from the aſhes of vegetables, and of the ſofter animal ſubſtances.

It is a conſiderable time ſince Mr. Margraaf publiſhed theſe diſcoveries. I can add further, that more lately, Monſ. Monnet, in France, has repeated and confirmed the experiments of Margraaf, and has added many new ones, which are entirely his own, and which ſhew that this earth is produced by nature in much greater quantity ſtill than was imagined. In making experiments with clays, and marles, and ſlate, he found that many of theſe contain a quantity of magneſia, mixed with the other earths, which compoſe the principal part of them. There is an extract of his diſcoveries on this ſubject in the *Obſervations de Phyſique* for June 1774, which well deſerves your peruſal, as a ſpecimen of well conducted inveſtigation, and as it contains much new information.

There is alſo a limeſtone, very abundant in the neighbourhood of Doncaſter, and, I believe, in other parts of England, which, when burnt, and laid on land as manure, is found greatly to injure its fertility. This has been examined lately by an intelligent chemiſt, and found to contain a very conſiderable proportion of magneſia.

When I reflected on the experiments already deſcribed, they appeared to me to lead to an explication of the nature of lime, which eaſily accounted for the moſt remarkable properties which we find in it, and for many phenomena relating to it and to other alkaline ſubſtances.

By theſe experiments it was made evident that magneſia and the vegetable alkali, in their ordinary ſtate, contain a large quantity of air, in an elaſtic, ſolid, or fixed ſtate, which makes up a conſiderable part of their bulk and weight; and that their efferveſcence with acids is a diſcharge or ſeparation of this air from the alkaline part of theſe ſubſtances,—the acid acting here in the ſame manner as the ſulphuric acid does when it expels the leſs powerful acids from the compound ſalts which contain them.

I therefore concluded, with reſpect to the other alkalis and alkaline earths, that their efferveſcence with acids depended on the ſame cauſe; that they all contain a large quantity of fixed air, which is expelled when they unite with acids; and that this air adheres to them with conſiderable force, ſince, notwithſtanding that it is ſuch a volatile ſubſtance, a full red heat is neceſſary to ſeparate it from magneſia, and the ſame red heat is not ſufficient to expel it entirely from the alkalis, or to deprive them entirely of their power of efferveſcing with acid ſalts.

I further was induced to think that the relation of alkaline ſubſtances to fixed air reſembled, in ſome particulars, their relation to acids; that, as the alkaline ſalts and earths attract acids ſtrongly, and, when ſaturated with them, become mild neutral ſalts, they, in the ſame manner, have an attraction for their fixed air, and, in their ordinary ſtate, are in ſome meaſure *neutralized* by it, appearing on this account milder, or leſs active bodies, than when we have an opportunity to examine them in a pure ſtate.

With reſpect to the calcareous earth in particular, I imagined that, when it is expoſed to the action of a ſtrong fire, and thereby converted into quicklime, the change it ſuffers depends on the loſs of the large quantity of fixed air which is combined with this earth in its natural ſtate; that this earth is expelled by the heat; and that the ſolubility in water, and the remarkable acrimony which we perceive in quicklime, do not proceed from any ſubtile or other matter

received in the fire, but are eſſential properties of this earth, depending on an attraction for water, and for thoſe ſeveral ſubſtances with which the lime is diſpoſed to unite; but that this attractive power or activity remains imperceptible, ſo long as the lime or calcareous earth is in its natural ſtate, in which it is ſaturated and neutralized by the air combined with it.

This ſuppoſition agrees much better with our general experience of the conſequence of combining and ſeparating different bodies in chemiſtry, than the opinion which then prevailed concerning the nature of lime. The eſtabliſhed opinion was, that quicklime was a compound, formed by the union of the calcareous earth with a ſubtile and active principle, ſuppoſed to be communicated to it by the fire or heat. But ſubtile and active ſubſtances, when combined with others, do not in general communicate their activity to theſe. Our general experience ſhews us that activity is diminiſhed by combination. We have a well known example of this in the combination of acids with alkalis. Both of theſe ſalts, in their ſeparate ſtate, have great activity and corroſive powers. When united, they form the neutral ſalts, which, inſtead of having the joint activity of their conſtituent parts, are mild and inert, if compared with either the acid or the alkali of which they are compoſed.

I therefore conſidered the calcareous earth as a peculiar, acrid, ſoluble earth, appearing commonly under a mild and inſoluble form, on account of its union with fixed air: and I conſidered quicklime as the ſame earth deprived of its air; and therefore ſhewing its proper ſolubility and acrimony, or its natural attraction for water, and for various other ſubſtances with which it is then capable of being combined.

This idea of the manner in which the calcareous earth becomes quicklime, not only agreed with our general experience of the conſequences of combination and ſeparation in chemiſtry, but was immediately ſupported by ſome capital facts belonging to this ſubject; and

which, at the ſame time, were quite inconſiſtent with the common opinion. It is well known, that when a calcareous ſtone or maſs is burnt to quicklime, it does not acquire any additional weight in the fire; but, on the contrary, ſuffers a very great loſs. The lime, when freſh drawn from the furnace, weighs generally no more than 60 per cent. of the weight of the limeſtone; and when I conſidered ſome experiments made ſome time before by Mr. Margraaf of Berlin, it appeared plain that the matter ſeparated from the limeſtone by heat, is an elaſtic aërial matter, incapable of being condenſed by cold into a palpable form. Theſe experiments are deſcribed in the Tranſactions of the Berlin Academy for 1748, and were made upon a particular calcareous ſubſtance of which he had undertaken the examination: It is called oſteocolla. He put eight ounces of oſteocolla, which is a calcareous earth, into an earthen retort, to which he joined a receiver, and ſet the retort in a proper furnace, where it was gradually heated to a violent degree. Nothing, however, was condenſed in the receiver, except two drachms of water, which, by its ſmell and properties, ſhewed itſelf to be ſlightly alkaline. He does not tell us the weight of the oſteocolla remaining in the retort: He only ſays that it was converted into quicklime; but this alone, and the heat he applied, are ſufficient proofs that it had loſt about three ounces of its weight; and as no more than the quarter of an ounce of water was found in the receiver, it is plain that this loſs was occaſioned chiefly by the ſeparation of an elaſtic aërial matter which could not be condenſed.

The ſame thing has ſince been more fully aſcertained by Profeſſor Jaquin of Vienna. In order to ſatisfy himſelf of the truth of my theory, he put a quantity of limeſtone, broken down to ſmall pieces, into an earthen retort, and ſet it in a furnace, in which it might be heated to a violent degree. A receiver, with a very ſmall hole drilled in the bottom of it, was luted to the retort, perfectly air-tight: Then fire was applied, and heat raiſed in a ſlow and regular manner.

1ſt, A very ſmall quantity of water was condenſed in the receiver.

This all came over in the beginning of the proceſs, and with a very low or moderate degree of red heat.

2*dly*, After this period of the diſtillation no more water came, though the heat continued increaſing; but an elaſtic fluid began to iſſue through the little hole of the receiver with a hiſſing noiſe, which continued a long time, but at laſt ceaſed. The limeſtone being then taken out, it was found to be excellent quicklime.

N. B. He repeated this proceſs and varied it. When he withdrew the fire, as ſoon as all the water was expelled, there was no quicklime; and when he continued it until a part only of the air was expelled, a part only of the ſtones were changed into lime, viz. from the ſurface inwards, and to a greater depth in proportion as the heat was continued nearer to that period at which the eruption of the air commonly ceaſed. This ſupported the idea of quicklime which I had propoſed.

But what further tends very much to ſupport it, is the facility with which it enables us to explain the greater part, if not the whole of this ſubject. That you may be ſatisfied of this alſo, I ſhall now ſtate ſome of theſe facts or phenomena which our theory explains.

Thus, to conſider in the firſt place, the ſlaking of lime, the formation of lime-water, and ſome of the qualities of lime-water: The calcareous earth, in its quicklime ſtate, or deprived of its air, as it has an attraction for water, will be found to reſemble the ſalts in ſeveral particulars in the mode of this attraction. The ſalts, if we take them in their pureſt ſtate, are diſpoſed to combine with water in two different ways. With a certain quantity of water they unite cloſely, and with conſiderable force, to conſtitute the cryſtals of ſalts,—in which the water is joined with the particles of ſalt in ſuch a manner as to become ſolid along with them. There are ſome of the ſalts which become very hot in uniting with this portion of water: Such are Glauber's ſalt, Epſom ſalt, fixed alkali, and ſeveral others. This heat is ſuppoſed by moſt authors to come out of the ſalts: I am rather inclined to think it

comes from the water. After this, if more water be added, the ſalt unites with it in a different manner, ſo as to become fluid along with it, or form a ſolution or liquid, in which the ſalt is diſſolved in the water; and, in this part of the proceſs, cold is produced. In the ſame manner, if water be added to quicklime, a certain quantity of it is attracted by the quicklime, and deprived of its fluidity with violence and heat; and it adheres to the lime with conſiderable force, conſtituting with it a dry powder, which is called flaked lime. But if this flaked lime be mixed with a much larger quantity of water, a part of it is diſſolved, and compoſes with the water a lime-water.

The heat produced in ſlaking lime, is juſt one of the numberleſs examples of the emerſion of latent heat: And if any perſon ſhould think that the heat produced in ſome of theſe inſtances is too great to be explained in this way, let him conſider that the 140 degrees, which eſcape from water in congelation, refers only to the difference between the heats neceſſary for appearing in the forms of water and ice; but we have no authority to ſay that the ſame abſtraction of heat from the ſame quantity of water, will ſuit its ſubſequent appearance in a cryſtal of Glauber's ſalt, Epſom ſalt, or nitre. A much greater emerſion may be neceſſary, or a much leſs; therefore, till the experiment be tried, we cannot ſay how much heat muſt emerge before the water can unite with quicklime in a ſolid form. And, let it be further remarked, that the heat extricated in this cryſtallization, can be very little diminiſhed by the ſubſequent ſolution, becauſe there is very little lime diſſolved in the lime-water.

When this fluid is expoſed to the open air, the particles of lime which are at the ſurface gradually attract fixed air, which is mixed with the atmoſphere; but while the lime is thus ſaturated with air, it is thereby reſtored to its original ſtate of mildneſs and inſolubility. And, as the whole of this change muſt happen at the ſurface of the lime-water, the whole of the lime is ſucceſſively collected there, in its original form of an inſipid calcareous earth, called the cream or cruſts of lime-water.

In forming this theory, I was neceſſarily led to perceive a diſtinction between atmoſpherical air, or the greater part of it, and that ſort of air with which the alkaline ſubſtances are diſpoſed to unite. It was plain that the lime of lime-water, for example, is not diſpoſed to unite with the whole maſs of atmoſpherical air that happens to be confined with it, or with every part of it equally. If this were the caſe, it would be impoſſible to preſerve lime-water in good condition, without extraordinary precautions to keep the air from ever entering the bottles or other veſſels in which it is contained. But we find, in fact, that it is not neceſſary for the preſervation of the lime-water, that we keep the air out of theſe bottles, or exhauſt them of air. They always contain as much air in the part of them that is not filled, as other bottles do in which we keep other fluids; and yet the lime-water may be preſerved good in them for a long time. The only circumſtances in which lime-water loſes its qualities, and throws up the lime to its upper ſurface, are, when we expoſe it to the open air, or keep it in bottles that are left open. From this it was evident, that the ſort of air with which the lime is diſpoſed to unite, is a particular ſpecies, which is mixed in ſmall quantity only with the air of the atmoſphere. To this particular ſpecies I gave the name of FIXED AIR, the only term then uſed to denote any air that is condenſed and fixed in different bodies, and is a part of their conſtituent principles.

To return to the explanation of the properties of quicklime.—

When quicklime itſelf is expoſed to the open air, it muſt gradually attract the humidity and the fixed air which are contained in the atmoſphere. And as our atmoſphere contains more of humidity than of fixed air, the change which the quicklime, when expoſed, undergoes the moſt readily, is a change of it into ſlaked lime. But it attracts alſo ſome fixed air, and continues afterwards to attract more, until it is gradually ſaturated with it, and thus is reſtored to its original mild and inſoluble ſtate.

To explain all the effects which are produced by mixing the alka-

line ſalts with lime or lime-water, we need only to ſuppoſe that the fixed air is more ſtrongly attracted by the lime than by the alkali. The lime in this caſe muſt attract the air from the alkali to itſelf, and muſt thereby return to a mild and inſoluble ſtate; while the alkali, on the contrary, becomes more corroſive,—that is, ſhews its proper degree of activity, or attraction for water, and its natural action on bodies of the inflammable kind, and thoſe of animals and vegetables; which attraction, and conſequent action, was neceſſarily weaker while the alkali was combined with its air, and in ſome meaſure neutralized by it. It therefore becomes what we call highly corroſive. And, in like manner, the volatile alkali, when deprived of its air by quicklime, beſides ſhewing a ſtronger attraction for water, ſhews alſo its proper degree of volatility, ſuch as we ſee it in the cauſtic volatile alkali prepared with quicklime; which high degree of volatility is diminiſhed or repreſſed in the common volatile alkali by the air adhering to it,—in the ſame manner as it is repreſſed in various degrees, by the union of this alkali with the different acids, according to their degrees of fixedneſs.

In like manner, the effects of magneſia, applied in its different ſtates to lime, or lime-water, are eaſily explained, by ſuppoſing that lime has ſuch an attraction for fixed air, that it has the power to take it from the earth of magneſia. When the magneſia is added to lime-water, the air is ſeparated from the magneſia by the ſtronger attraction of the lime; and as the lime, when ſaturated with air, does not become active, or perceptibly ſoluble in water, the lime-water becomes inſipid,—the lime which it contained being depoſited at the bottom of the mixture along with the magneſia. But, if we make this experiment with magneſia which has been deprived of its air by heat before it be added to the lime-water, this fluid ſuffers no perceptible change.

This account of the nature of lime recommended itſelf, therefore, by thus affording an eaſy explanation of many of the facts relating to quicklime and lime-water; and the effects of mixing theſe with alkaline ſalts, and with magneſia, in different ſtates.

But, while I was employed in conſidering it with more attention, I found it to be neceſſarily connected with conſequences which were contrary to what were at that time eſteemed to be facts, or truths, eſtabliſhed upon experience. And the conſideration of theſe began to raiſe ſome doubts concerning the ſolidity of the whole of my ſyſtem. In every other reſpect, however, it had ſo much the appearance of being well founded, that I reſolved to conſider more particularly theſe unavoidable conſequences of the theory, and not to truſt to the common opinion of what was fact, but aſſure myſelf of what was really ſo, by making experiments.

I therefore found, that the conſequences I ſpeak of were reducible to theſe propoſitions:

1. If we only expel fixed air from the calcareous earth when we burn it to quicklime, the quicklime thus formed muſt diſſolve in acids without efferveſcence; and, notwithſtanding the loſs of weight it ſuffered in the fire, it muſt ſaturate the ſame quantity of acid as the whole of the calcareous earth would have done from which it was made. And the ſame qualities muſt alſo be found in the alkaline ſalts when rendered cauſtic by lime.

2. If quicklime be only a calcareous earth deprived of its air, and whoſe attraction for fixed air is ſtronger than that of alkalis, it follows, that, by adding to it a ſufficient quantity of alkali ſaturated with air, the lime will recover the whole of its air, and be entirely reſtored to its original weight and condition. And it alſo follows, that the earth precipitated from lime-water by an alkali, muſt be the lime which was diſſolved in the water reſtored again to its original mild and inſoluble ſtate, by having attracted the fixed air from the alkali.

3. If it be ſuppoſed, that ſlaked lime is an uniform compound of lime and water, and does not contain any parts which are more fiery, active, ſubtile, or ſoluble than the reſt, it follows, that as part of it can be diſſolved in water, the whole muſt be capable of diſſolution in that fluid.

4. If the exceſſive acrimony of the cauſtic alkali depends on its being free from air, and not upon a part of the lime adhering to it, a clear cauſtic ley will conſequently be found free from any admixture of lime, except it ſhould happen by accident, when the quantity of lime employed in making it is much greater than what is ſufficient to extract the whole air of the alkali; for then we can imagine, that as much of the ſuperfluous lime may be diſſolved by the ley as would be diſſolved by pure water, or that the ley may contain as much lime as lime-water does.

5. It was proved by the former experiments that alkaline earths loſe their air when they are joined to an acid, but recover it if ſeparated again from that acid by an ordinary alkali,—the air paſſing from the alkali to the earth at the ſame time that the acid paſſes from the earth to the alkali.

If the cauſtic alkali be deſtitute of air, it muſt, therefore, precipitate magneſia from acids in the form of a magneſia free of air, or which will not effervеſce with acids. And the ſame cauſtic alkali muſt precipitate the calcareous earth from acids in the form of a calcareous earth deſtitute of air, and ſaturated with water only, or in the form of ſlaked lime.

Theſe were the conſequences of the theory which required the moſt attentive examination, as being either quite new and unheard of, or inconſiſtent with the eſtabliſhed opinions. I was encouraged, however, to proceed in the inquiry by one or two facts which coincided with theſe propoſitions. One of theſe was the nature of the cauſtic volatile alkali. Mr. Boerhaave having prepared ſome of this with the greateſt care, was ſurpriſed to find that it did not effervеſce with acids. He calls it *liquor omnium acerrimus, neque tamen alcalinus*. Thinking effervеſcence with acids an eſſential character of alkaline ſubſtances, he thought that he had deſtroyed it. And the other was a paſſage in Hoffmann, in which he ſays, that in making ſome

experiments with quicklime, he once found that it was diſſolved by acids without efferveſcence.

I accordingly engaged in a ſet of experiments for proving the truth or falſity of theſe propoſitions: And the conſequence was, that they, in general, proved true, or agreeable to the theory. But it may be proper to give a ſhort account of the experiments, that I may have an opportunity not only to explain this ſubject more fully, but alſo to mention ſome other diſcoveries which have been the conſequence of this ſet of experiments.

Experiments to try the Firſt Propoſition.

To examine the truth of this propoſition, it was neceſſary, in the firſt place, to learn the quantity of acid required to diſſolve and ſaturate the calcareous earth in its natural ſtate, in order to compare this quantity of acid with the quantity required to diſſolve and ſaturate it when in the ſtate of lime.

I therefore put 120 grains weight of chalk into a Florentine flaſk with a ſmall quantity of water, and placing the flaſk on the ſcale of a balance, I counterpoiſed it by putting ſand in the other ſcale. I then gradually ſaturated and diſſolved the chalk with the muriatic acid diluted, as related in ſimilar experiments on the fixed alkali and on magneſia: 421 grains weight of the diluted acid completed the diſſolution of the chalk; and the loſs of weight by the efferveſcence was 48 grains.

Being thus inſtructed by this previous experiment, I took another bit of choſen chalk, of the ſame weight with the former. I expoſed it to a proper heat for changing it into perfect quicklime, in a ſmall quantity of diſtilled water, and then diſſolved it in the ſame manner as I had diſſolved the chalk in the laſt experiment, and with ſome of the ſame diluted muriatic acid: 414 grains of this acid were required to complete the diſſolution. This was accompliſhed without the leaſt efferveſcence or loſs of weight.

This experiment, therefore, eſtabliſhed the truth of the firſt propoſition, with reſpect to the calcareous earth, by ſhewing that quicklime, when well prepared, and made as perfect as poſſible, can be diſſolved in acids, without effervescence, or any loſs of weight. It is alſo a ſufficient proof that quicklime requires as much acid to ſaturate and diſſolve it as the quantity of calcareous earth of which it was made would have done. For although the quantity of acid required for diſſolving the 68 grains of quicklime in this experiment was not quite ſo great as the quantity required for diſſolving the 120 grains of chalk, the difference is ſo ſmall that it is not worth notice. The difference of weight between the chalk and the lime was 52 grains in 120. The difference between the quantity of acid required for diſſolving them was only 7 in 421, and even this difference can be accounted for. We know by experience, that in ſeparating volatile from fixed ſubſtances by the power of heat, a ſmall portion of the fixed is commonly or often carried away by the volatile matter. It is therefore probable that a little of the calcareous earth or lime is carried away when this laſt is driven off by the action of a violent fire. This appears, I think, in Jaquin's experiment. The calcareous earth yielded, in diſtillation, water which was ſlightly alkaline. This water would have ſaturated ſome acid. For this reaſon the lime can be diſſolved by a little leſs of the acid than if none of it had been loſt.

It was, however, the eſtabliſhed opinion at the time when I firſt made this experiment, that quicklime or ſlaked lime effervesced with acids as the calcareous earth does; the experiments before that time having been moſtly made with imperfect lime, in conſequence of the want of knowledge of the true nature of lime, and of what was neceſſary to make it perfect, and to preſerve it in that ſtate.

Having thus aſcertained the truth of the firſt propoſition, with regard to lime, I made ſome experiments with the cauſtic fixed alkali, to learn whether theſe alſo would agree with what was indicated in the firſt propoſition.

I prepared a cauſtic ley by firſt ſlaking 26 ounces of very good quicklime made of chalk, with nearly ſeven times its weight, or eleven pounds of boiling water, in a glaſs veſſel, and then adding 18 ounces of purified pearl aſhes, diſſolved in two pounds and a half of water. The mouth of the veſſel was cloſely covered. This warm mixture was ſhaken frequently for two hours, at the end of which the action of the lime on the alkali was ſuppoſed to be over, and nothing remained to be done but to ſeparate them again from one another: I therefore added 12 pounds of water, ſtirred up the lime, and, after allowing it to ſubſide again, I poured off as much of the clear ley as poſſible, which was immediately corked up in bottles.

The lime and alkali were mixed together in this proceſs at firſt by the medium of ſo much water only as reduced the mixture to the conſiſtence of thick cream; for this reaſon, that they are thus kept in perpetual contact and equal mixture, until they have acted ſufficiently on one another. When more water is uſed in the beginning of this operation, the lime ſubſides to the bottom; and, though often ſtirred up, does not act ſo ſtrongly on the alkali, which is uniformly diſſolved in every part of the liquor. But I added more water afterwards to dilute the mixture, that the lime might ſubſide, and the clear liquor containing the alkali might be decanted from it.

The cauſtic ley prepared in this manner was found, upon trial, to mix with acids, and to neutralize them, without the leaſt effervescence or loſs of weight: And when ſome of it was added to lime-water, it produced only a very ſmall diminution of tranſparency, but not a precipitate, like that produced by an alkaline ſalt in its ordinary ſtate. This was a ſure ſign of its being a perfect, or very nearly perfect cauſtic alkali, or of its being deprived of the whole, or very nearly the whole, of its fixed air, by which the common alkalis precipitate the lime from lime-water.

This is the ſevereſt teſt of a cauſtic ley. A remainder of air, which will not make any ſenſible effervescence with acids, is ſufficient for

ſaturating a minute portion of the lime contained in lime-water, and rendering it perceptible by a ſlight want of colourleſs tranſparency.

By evaporating a part of the ley, to learn the quantity or weight of the cauſtic alkali it contained, I alſo ſatisfied myſelf that the alkali was not increaſed, but diminiſhed in weight, by being made cauſtic; and that it required much more acid to ſaturate it than an equal quantity of the common fixed alkali does.

I muſt obſerve that many precautions muſt be taken for this evaporation to dryneſs. The cauſtic alkali requires a low red heat for expelling all the water; and is ſo acrid in this ſtate as to corrode common earthen ware, and even copper and iron. I evaporated it therefore in a thin ſilver bowl. It is not eaſy to know by the look of it when all the water is gone, for the ſalt is then fluid, and as tranſparent as the ley. I knew it to be as much cleared of water as I could hope to accompliſh, by obſerving the bottom of the bowl beginning to be viſible in the dark: It was then removed from the fire, and quickly congealed into a hard cake.

Thus far the experiments ſupported the truth of the firſt propoſition, in every part, and gave encouragement to proceed to the verification of the other propoſitions, or to try if they would be verified by proper experiments.

Examination of the Second Propoſition.

If quicklime be only a calcareous earth deprived of its air, and having an attraction for fixed air ſtronger than that of alkalis, then, by adding to it a ſufficient quantity of alkali in its ordinary ſtate, the lime ſhould recover the whole of its air, and be reſtored to its original weight and condition. And it is alſo a conſequence, that the earth precipitated from lime-water by an alkali muſt be the lime which was diſſolved in the water, reſtored again to its original mild and inſoluble ſtate, by having attracted the fixed air from the alkali.

With reſpect to all theſe points, the following experiments were made:

A piece of perfect quicklime, made from 120 grains of chalk, and which weighed 68 grains, was ground to a fine powder, and thrown into a clear ſolution of an ounce of alkali of tartar in two ounces of water. This mixture, being digeſted ſome time, was then diluted with more water; and the alkaline liquor was carefully waſhed away from the lime by repeated affuſions of pure water, and ſubſequent decantations of it from the ſediment. The lime or ſediment being then dried, weighed 118 grains, although the piece of quicklime from which it was made weighed only 68 grains. It was quite mild; and ſimilar in every trial to a fine powder of common chalk. It effervеſced violently with acids; and was therefore ſaturated with air, which muſt have been ſupplied by the alkali. The weight of it was not made up completely to the weight it had before it was burnt; but the deficiency is only of two grains, and this can be accounted for upon the principle I mentioned formerly, that a very ſmall portion of the lime itſelf is volatilized and carried away by the air in a violent heat.

In order to examine the earth which is precipitated from lime-water by alkaline ſalts, 60 grains of the alkali of tartar were diſſolved in 14 pounds of lime-water, and the earth thereby precipitated was carefully collected on a filtre and dried; it weighed 51 grains. When afterwards expoſed to a ſufficient heat, it was converted into a true quicklime, and had every other quality of the calcareous earth. And this experiment being repeated with volatile alkali, and alſo with the foſſil alkali, the reſult was exactly the ſame as when the alkali of tartar was uſed; the precipitated earth being always a calcareous earth. This was a ſufficient proof that the propoſition was true.

Examination of the Third Propoſition.

If it be ſuppoſed that ſlaked lime is an uniform compound of lime and water, and does not contain any parts which are more fiery, active, ſubtile, or ſoluble than the reſt; it follows, that as part of it can

be diſſolved in water, the whole of it muſt be capable of diſſolution in that fluid.

This propoſition had, at that time, leſs appearance of probability than any of the former. It was univerſally believed that lime was only partially ſoluble in water; and different opinions were entertained of the proportion of it that could be diſſolved. Dr. Alſton contended that a fourth part of it, or perhaps a little more, might be diſſolved, provided a very large quantity of water was employed; ſuch as 500 times the weight of the lime. But the general opinion was that a much ſmaller portion of it only was ſoluble and active. The queſtion had never been decided by an accurate experiment.

I therefore choſe a bit of chalk, which, when heated to a ſufficient degree in a crucible, afforded a little maſs of perfect quicklime, weighing eight grains. This little maſs was thrown, while yet warm, into a ſmall quantity of warm diſtilled water in a phial, in which it was ſoon ſlaked, and formed a white mixture like milk. This mixture was immediately poured into a larger glaſs veſſel, in which I had eighteen ounces of diſtilled water.

While the milky mixture was diffuſed through the water, the lime was ſeen to diſſolve almoſt entirely; nothing remained undiſſolved but a very light fæculency, which was almoſt tranſparent, or only like thin clouds in the liquor. This fæculency, when it was allowed to ſubſide, and was collected with the greateſt care on a ſmall filtre and dried, weighed only the third part of a grain. In ſome repetitions of the experiment it weighed leſs, and in others a little more. Being examined by putting it on a plate of glaſs, and adding a drop of diluted nitric acid, it was diſſolved in part, with effervеſcence, but a part of it remained undiſſolved, which was ochre of iron. It appeared, therefore, to be compoſed of a minute portion of the lime, which had ſomehow recovered fixed air, and of ochre of iron, and perhaps a little clay, which are well known to be often preſent, in ſmall quantity, in chalk.

We may therefore reaſonably conclude from this experiment, that lime, when it is quite pure and perfect, is totally ſoluble in pure water. And that the reaſon why it had appeared hitherto ſoluble only in part, was, that the experiment had never been made with perfect lime and with pure water. The water taſted ſtrongly of the lime; it was a true lime-water, and yielded twelve grains of calcareous earth, when ſome alkali of tartar was added to it.

The event of this experiment was even more favourable than I had expected. I expected a much larger quantity of ſediment produced from this lime when diſſolved; chiefly becauſe I ſuſpected that the air, which we all know to be commonly diſſolved in water, might be attracted by the alkaline ſubſtances, and therefore render the lime mild and inſoluble. The reſult rather ſurpriſed me, and, raiſing new thoughts in my mind, which ſeemed to lead to very extenſive and important conſequences, I was anxious to put it to ſome trial.

To learn, therefore, whether water ſaturated with lime had given up the air which it uſually holds in ſolution, and whether that air is united with the lime, I made a very ſtrong lime-water, and placed four ounces of it under the air-pump receiver, along with four ounces of common water in another veſſel of the ſame ſize. The air was taken out of the receiver; and while this was doing, air bubbles formed and aroſe in both phials, in equal quantities, and in the ſame manner, as far as I could judge; and the lime-water continued perfectly tranſparent.

Hence it is evident that the air ariſing from the lime-water had been combined with the water, and not with the lime; and the air which water commonly holds in ſolution is of a different nature from that which is attracted by lime and alkalis: For, had it been the ſame, and combined with the lime, as fixed air is, the removal of the atmoſpherical preſſure would not have been ſufficient for occaſioning its ſeparation.

Quicklime, therefore, does not attract the air that is uſually contained in common water, nor does it attract the whole of the maſs of atmoſpherical air, as I have already obſerved. It attracts only a particular kind of aërial fluid which is mixed with the air of the atmoſphere, in the way of common diffuſion, in a ſmall quantity only. It is mixed as ſpirits are in water, or one metal with another, without any change of properties; and alkaline ſubſtances take out this air, as aquafortis takes out the ſilver which alloys a piece of gold.

Here a new, and perhaps boundleſs field ſeemed to open before me. We know not how many different airs may be thus contained in our atmoſphere, nor what may be their ſeparate properties. This particular kind has evidently very curious and important ones. It renders mild and ſalutary the moſt acrid and deſtructive ſubſtances that we know. I reſolved to begin the ſtudy of them, by a cloſer examination of the ſpecies which I had fortunately diſcovered.

I gave it the name of Fixed Air, for the reaſons already mentioned, a term which was then common to denote any elaſtic matter, capable of entering into the compoſition of bodies, and of being condenſed in them to a ſolid concrete ſtate, by its chemical attraction for ſome of their conſtituent parts. The name may perhaps be thought to be not very judiciouſly choſen, to denote this matter in its elaſtic ſtate; and accordingly it has now been changed for gas. But I choſe rather to employ a term already familiar, than invent a new name, before I was well informed reſpecting the peculiar properties of this ſubſtance.

It is ſomewhat ſingular, that when a ſolution of mild alkali is rendered cauſtic by lime, the ſpecific gravity is conſiderably diminiſhed. We ſhould naturally expect the contrary effect, from the abſtraction of ſo rare a fluid as air. But this ſhews, that in the ſolution the fixed air is rendered conſiderably denſer than water, being reduced to leſs than $\frac{1}{800}$ of its aërial bulk.

I fully intended to make this air, and ſome other elaſtic fluids which frequently occur, the ſubject of ſerious ſtudy. But my attention was then forcibly turned to other objects. A load of new official duties was then laid on me, which divided my attention among a great variety of objects *. In the ſame year, however, in which my firſt account of theſe experiments was publiſhed, namely 1757, I had diſcovered that this particular kind of air, attracted by alkaline ſubſtances, is deadly to all animals that breath it by the mouth and noſtrils together; but that if the noſtrils were kept ſhut, I was led to think that it might be breathed with ſafety. I found, for example, that when ſparrows died in it in ten or eleven ſeconds, they would live in it for three or four minutes when the noſtrils were ſhut by melted ſuet. And I convinced myſelf, that the change produced on wholeſome air by breathing it, conſiſted chiefly, if not ſolely, in the converſion of part of it into fixed air. For I found, that by blowing through a pipe into lime-water, or a ſolution of cauſtic alkali, the lime was precipitated, and the alkali was rendered mild. I was partly led to theſe experiments by ſome obſervations of Dr. Hales, in which he ſays, that breathing through diaphragms of cloth dipped in alkaline ſolution, made the air laſt longer for the purpoſes of life †.

In the ſame year I found that fixed air is the chief part of the elaſtic matter which is formed in liquids in the vinous fermentation. Van Helmont had indeed ſaid this, and it was to this that he firſt gave the name *gas ſilveſtre*. It could not long be unknown to thoſe occupied in brewing or making wines. But it was at random that he ſaid it was the ſame with that of the Grotto del Cane in Italy, (but

* Dr. Black was at this time elected Profeſſor of Medicine and Chemiſtry in the Univerſity of Glaſgow. EDITOR.

† In the winter 1764-5, Dr. Black rendered a conſiderable quantity of cauſtic foſſil alkali mild and cryſtalline, by cauſing it to filtre ſlowly by rags, in an apparatus which was placed above one of the ſpiracles in the cieling of a church, in which a congregation of more than 1500 perſons had continued near ten hours. EDITOR.

he ſuppoſed the identity, becauſe both are deadly); for he had examined neither of them chemically, nor did he know that it was the air diſengaged in the efferveſcence of alkaline ſubſtances with acids. I convinced myſelf of the fact by going to a brew-houſe with two phials, one filled with diſtilled water, and the other with lime-water. I emptied the firſt into a vat of wort fermenting briſkly, holding the mouth of the phial cloſe to the ſurface of the wort. I then poured ſome of the lime-water into it, ſhut it with my finger, and ſhook it. The lime-water became turbid immediately.

Van Helmont ſays, that the *dunſte*, or deadly vapour of burning charcoal, is the ſame gas ſilveſtre; but this was alſo a random conjecture. He does not even ſay that it extinguiſhes flame; yet this was known to the chemiſts of his day. I had now the certain means of deciding the queſtion, ſince, if the ſame, it muſt be fixed air. I made ſeveral indiſtinct experiments as ſoon as the conjecture occurred to my thoughts; but they were with little contrivance or accuracy. In the evening of the ſame day that I diſcovered that it was fixed air that eſcaped from fermenting liquors, I made an experiment which ſatisfied me. Unfixing the nozzle of a pair of chamber-bellows, I put a bit of charcoal, juſt red hot, into the wide end of it, and then quickly putting it into its place again, I plunged the pipe to the bottom of a phial, and forced the air very ſlowly through the charcoal, ſo as to maintain its combuſtion, but not produce a heat too ſuddenly for the phial to bear. When I judged that the air of the phial was completely vitiated, I poured lime-water into it, and had the pleaſure of ſeeing it become milky in a moment.

I now admired Van Helmont's ſagacity, or his fortunate conjecture; and, for ſome years, I took it for granted that all thoſe vapours which extinguiſh flame, and are deſtructive of animal life, without irritating the lungs, or giving warning by their corroſive nature, are the gas ſilveſtre of Van Helmont, or fixed air.

Some time after I had made, and publiſhed in my inaugural diſſer-

tation, the experiments you have ſeen, the attention of ſome other perſons was excited, and keenly engaged with this new and intereſting ſubject. The late Dr. Macbride of Dublin began to attend to it, in conſequence of ſome letters which I wrote to my friend Dr. Hutcheſon, then lecturer on chemiſtry in Trinity College. In theſe letters I deſcribed to him ſome of my newly contrived experiments and apparatus, of which Dr. Macbride made uſe in his inveſtigations.

He made a great number of experiments to ſhew that the air emitted from fermenting vegetables is, in all caſes, an air of this kind; that it is attracted by alkaline ſalts and earths, and precipitates lime from lime-water. He alſo obtained ſome of this air from animal ſubſtances in a putrefying ſtate; and he thought that when applied in quantity to putrefying animal ſubſtances, it ſtopped putrefaction, and even reſtored putrid ſubſtances to a ſound ſtate.

Concluding from what he thought was proved by his experiments, he conſidered this ſort of air as an element neceſſary, or of great importance, in the compoſition of moſt kinds of matter. He imagined that the coheſion of the parts of ſolid bodies depends on it, and that putrefaction, and the concomitant reſolution of bodies into their firſt principles, are entirely a conſequence of the ſeparation or loſs of this kind of air, which he ſuppoſed to be the great cementing principle of ſolid bodies.

But this ſyſtem was not well founded, and was not only not ſupported, but, in ſome meaſure, refuted afterwards, by the experiments and diſcoveries of other authors. The Doctor having obſerved that ſome effervеſcence or ebullition accompanies many caſes of the diſſolution of ſolid bodies by putrefaction, and ſome other natural operations, he ſuppoſed that in all theſe caſes, air like this was ſeparated from the materials, and that the ſeparation of this air was the circumſtance moſt effectual, or even eſſential to the diſſolution.

But, by a little more knowledge of chemiſtry, he would ſoon have

learned that he was wrong with reſpect to a great number of ſuch caſes; for later experiments on the putrefaction of animal ſubſtances have ſhewn that the elaſtic fluid matter emitted by theſe is only in part this kind of air,—by much the greater part being an inflammable vapour, and other kinds.

Next after Dr. Macbride, the Honourable Henry Cavendiſh publiſhed, in the Philoſophical Tranſactions 1765, ſome neat and ingenious experiments on this ſort of air and ſome other elaſtic fluids.

He, in the firſt place, ſhewed that this air, when ſeparated from alkalis or earths by acids, is beyond all doubt a permanent elaſtic fluid. He kept ſome of it twelve months in a veſſel inverted into mercury, without any diminution of its elaſticity.

Dr. Macbride had before diſcovered that water could abſorb a quantity of this air, and become thereby capable of precipitating lime from lime-water. Mr. Cavendiſh demonſtrated this by more deciſive experiments, and has determined the full quantity which the water can abſorb. When of a middle temperature of heat, or about 55°, it will abſorb rather more than an equal bulk.

From Mr. Cavendiſh's experiments, it appears that when the water is warm, it does not abſorb the air ſo readily, nor ſo much of it; and after cold water is ſaturated with it, if we make it hot to a certain degree, the air is ſeparated, forming itſelf into bubbles which ariſe out of the water. It alſo eſcapes ſlowly and imperceptibly, if the water be left in an open veſſel, atmoſpherical air having rather more attraction for this ſort of air than water has.

Mr. Cavendiſh alſo diſcovered that other fluids beſide water can abſorb ſome of this air; as ſpirit of wine, which abſorbs more than twice its bulk; and ſome of the oils abſorb as much as water does. In theſe experiments with water and other fluids, he thought there was reaſon to infer that this air is not homogeneous, but that ſome parts of it are more abſorbable than the reſt, and that a certain

part of it could not be abſorbed. I ſuſpect, however, that this was a deception, proceeding from the common air which water contains, and which ariſes with the fixed air during the extrication of this laſt from the alkaline ſubſtances.

From ſome of his experiments, Mr. Cavendiſh calculated with great exactneſs the quantities of this air contained in marble, in pearl-aſhes or common fixed alkali, in volatile alkali, and in magneſia, when theſe alkaline ſubſtances are in their ordinary ſtate. And he thereby explained ſome phenomena which occur in mixing the alkalis with ſolutions of marble, or of magneſia by acids.

Thus he found that marble contained $\frac{407}{1000}$ of fixed air.

Mild volatile alkali -	$\frac{533}{1000}$
Pearl aſhes - -	$\frac{285}{1000}$
Cryſtals of ſoda - -	$\frac{423}{1000}$
Magneſia - - -	$\frac{594}{1000}$

And that a certain quantity of acid ſaturated—

Of marble - - -	1000 grains.
Mild volatile alkali -	1661
Pearl aſhes - -	1558
Cryſtals of ſoda - -	2035

Cryſtals of ſoda effervеſce with a ſolution of chalk in an acid. They do not precipitate magneſia without heat; and a conſiderable effervеſcence attends the precipitation. Mild volatile alkali effervеſces alſo with a ſolution of magneſia in an acid; and frequently does not precipitate it, but yet detaches it from the acid, and rediſſolves it by the fixed air which is extricated.

He alſo aſcertained the preciſe denſity of this air, which he has ſhewn to be greater than that of common air, in the proportion of 157 to 100; and has ſhewn that the air of marble and of fermenting vegetables agree in this as well as in other reſpects. In conſequence of this, it lies at the bottom of a veſſel, and may be poured

out like water. When thus poured out on a candle, it extinguiſhes it as water would do. It affords an amuſing ſpectacle by letting a large ſoap-bubble fall on it in a veſſel. The bubble rebounds from it like a football, and ſeems to reſt on nothing. A burning candle may be held in it, having the top of the wick about half an inch under the ſurface, in which caſe the flame will continue for a few ſeconds, but altogether detached from the candle. The wick remains hot enough to cauſe the tallow ſtill to evaporate; and the vapour kindles at the ſurface of the fixed air. The floor of the Grotto del Cane, in Italy, is lower than the door; and this hollow is always filled with fixed air, which can riſe no higher than the cill, or threſhold of the door, but flows out like water. If a dog go in, he is immerſed in the fixed air, and dies immediately: But a man goes in with ſafety, becauſe his mouth is far above the ſurface of this deleterious air.

He alſo mixed this air with common air, in different proportions, to diſcover what effect theſe mixtures had upon flame or burning bodies. All his experiments are ingeniouſly contrived, and executed with accuracy.

Immediately after Mr. Cavendiſh had publiſhed his experiments, ſome of them, particularly thoſe which ſhew that water is capable of abſorbing ſuch a large quantity of this air, recalled the attention of Dr. Brownrigg to an opinion he had long entertained, and had communicated, with his reaſons for it, to the Royal Society ſo early as the year 1741. The Doctor had been at Spa, where the appearance of the waters had drawn his attention. They are among the moſt remarkable of thoſe waters called *acidulæ*. They have a pleaſant light acidity and briſkneſs, and ſparkle in the glaſs like a fermented liquor. They appear as if ſomething very elaſtic and volatile were contained in them. He alſo obſerved, that not far from their fountain, there are caverns which contain the choke-damp, and that ſomething like the choke-damp hovers upon the water, by which ducks are killed.

He therefore ſuppoſed that the waters derived theſe qualities from

a quantity of this choke damp combined with the water, the nature of which choke-damp, however, was at that time unknown, excepting its power to kill animals immerſed in it, and to extinguiſh flame.

When Dr. Brownrigg ſaw Mr. Cavendiſh's experiments, he became ſtill more inclined to this opinion of the nature of the waters at Spa; and very ſoon after going back to that place, he gave a full demonſtration or proof of it, in a number of experiments made with the waters on the ſpot, which ſhewed that they do in reality contain a conſiderable quantity of a ſort of air, which, when ſeparated from the water by heat, kills animals. And it further appeared, by the experiments of others, that common water, when combined with this ſort of air, extracted by art from alkaline ſubſtances, acquires all the remarkable qualities of the acidulous mineral waters. From hence has ariſen the art of imitating thoſe waters exactly, by an artificial compound of this air with water, by ſmall additions of ſome of the ſalts, or alkaline earths, or iron, which, by accurate analyſis, have been found variouſly mixed in the compoſition of mineral waters. When this air is combined with pure water, the water acquires the briſkneſs and light ſouriſh pungent taſte of the acidulous mineral waters, and like them, has the power to change the infuſion of litmus to a red colour.

Thus, Dr. Brownrigg explained ſome of the qualities of the moſt remarkable mineral waters, which had never before been well underſtood. But our knowledge of ſome varieties of natural waters was made ſtill more perfect by the further diſcoveries of Mr. Cavendiſh and Mr. Lane. Many waters are well known to have a petrifying quality. They depoſit a calcareous earth in the pores or on the ſurface of different ſubſtances which are expoſed to them; or at leaſt they cover the inſides of tea-kettles with a calcareous incruſtation. There are other waters which contain a ſmall quantity of iron diſſolved in them, but which are ſure to depoſit the whole of it in the

form of ochre, if they are expoſed to the air, or are corked up in bottles not ſufficiently cloſe. Mr. Cavendiſh, while employed in examining a water near London, at Rathbone Place, diſcovered that calcareous earth can be diſſolved by aërated water; and that it is depoſited when ſuch water is deprived of its air; and that the water of Rathbone Place actually contained calcareous earth diſſolved in this manner.

This diſcovery explains the nature of moſt petrifying waters. They contain a ſmall quantity of calcareous earth, diſſolved in this manner, and ſome perhaps of the earth of magneſia; for this earth alſo can be diſſolved by water charged with fixed air, and even more eaſily, and in greater quantity, than the calcareous earth. When ſuch waters are boiled often in tea-kettles, the air is driven away by the heat; and the earth ſeparates from the water, forming the earthy incruſtation that is found on the inſide of them. The earth is alſo depoſited more ſlowly when ſuch waters are long expoſed to the air, or run along the ſurface of the ground, and ſuffer evaporation. The fixed air, in this caſe, evaporates, and the earth often forms incruſtations, and ſtalactites, and petrifactions.

It may appear to you ſurpriſing that the ſame ſubſtances which, added to lime-water, precipitate the lime, by making it inſoluble, ſhould alſo be the cauſe of its rediſſolution when added in larger quantity. But the fact is certain, and it is not ſingular. There are many other facts in chemiſtry which are ſimilar to it: For example, moſt of the compound ſalts can be made more ſoluble in water than they are in their perfect or neutral ſtate, by adding to them a ſuperfluous quantity of acid. A certain quantity of this ſuperfluous acid joins itſelf to the compound ſalt with a weak attraction, and forms an acidulous compound ſalt, which is more ſoluble in water than the perfect neutral. There is no exception to this but in the compounds with acid of tartar, which, in this acidulous ſtate, are leſs ſoluble than in their neutral ſtate; and differ alſo in this, that the ſuperfluous acid is ſtrongly

united. All the other compound ſalts become more ſoluble in water by being acidulated with ſome ſuperfluous acid; which however adheres to them with an attraction that is very weak. The phenomenon you have now ſeen appears to be analogous to this. The firſt effect of the aërated water on the lime-water is to precipitate the lime, by ſupplying it with that quantity of fixed air which changes the lime into chalk, which, though not perfectly inſoluble, is very nearly ſo. But after this, if we add more of the aërated water, a ſuperfluous quantity of fixed air joins itſelf to this chalk, and forms what may be called *acidulous chalk*, which is more ſoluble than chalk. But this ſuperfluous quantity of fixed air adheres to the chalk with a weak attraction, and is ſeparated and driven off from it by the heat of boiling water, and alſo by the attraction of atmoſpherical air. We cannot therefore reduce this acidulous chalk to a dry ſtate. It is ſure to loſe its ſuperfluous quantity of fixed air when we attempt to evaporate the water from it; and then it becomes common chalk. The ſolution of a ſaline cryſtal is alſo analogous to this phenomenon.

From all this, you will eaſily underſtand the neceſſity of one ſtep of the proceſs, which I recommended, for preparing magneſia from Epſom ſalt. The ſtep I mean is the boiling over the fire, for a little while, the mixture which contains the ſolution of Epſom ſalt and the ſolution of potaſh, by which the magneſia is precipitated.

The reaſon of the neceſſity for boiling this mixture is, that a great quantity of fixed alkali is neceſſary for the complete precipitation of the magneſia; and this proceeds from the great quantity of acid which is united to the magneſia in Epſom ſalt. I found that one pound of pearl aſhes, or little leſs, is neceſſary for precipitating the magneſia completely from a pound of Epſom ſalt, although that ſalt contains one half of its weight of water in its cryſtals.

When the pound of alkali therefore unites with the acid, although there is no viſible effervescence, ſo great a quantity of air is extricated from it, that this air is ſufficient, not only for ſaturating the magneſia,

but for acidulating both it and the cold water with which the mixture is made; and conſequently, a great part of the acidulated magneſia is diſſolved in the acidulous water. But the mixture being boiled, the ſuperfluous air evaporates from the water and from the magneſia; and thus the magneſia is completely precipitated. This procedure, which explains a very extenſive and curious natural phenomenon, was diſcovered by Mr. Cavendiſh. The nature of the volatile chalybeate waters, which, when freſh from the ſpring, hold ſome iron in ſolution, and ſparkle in the glaſs, but loſe their briſkneſs and inky taſte by careleſs keeping, and gradually depoſit the iron in form of a red, or brown, or yellow ochre, were explained in the ſame manner by Mr. Lane. The iron had been diſſolved by the acidulous water containing fixed air.

It will perhaps appear to ſome of you ſurpriſing that any phyſician ſhould have been ſo bold as to think of giving this ſubſtance internally, when it is known to extinguiſh life ſo ſuddenly when applied to the lungs and organs of ſmell (for this ſeems a neceſſary condition). But the truth is, that theſe dangerous and fatal effects of it happen only if applied in that particular manner. It has no ſuch effect when applied to the nerves of the ſtomach, or other parts. On the contrary, we have daily experience that it is grateful to the ſtomach, and has a moſt agreeable, refreſhing, and cooling effect when applied there. This appears, both from the agreeable effect of acidulous waters on the ſtomach, and from that of very briſk fermented liquors, ſuch as champagne, beer, &c. which are highly grateful in hot climates. Even to the lungs, fixed air may be applied, not only with ſafety, but even with advantage, as we are informed by practitioners, who have tried it in conſumption and ulcerated lungs. But it muſt be employed with four or five times its bulk of atmoſpherical air, or even in a greater proportion. Were it to be breathed in conſiderable quantity in its pure ſtate, I have no doubt but that it would extinguiſh life in a ſhort time.

Thoſe who ventured to apply fixed air to the lungs, were induced

to this by obſerving its effects on ſome very bad external ulcers, to which it proved an uſeful ſtimulant, and a powerful corrector of the putrid and acrid humours which bad ulcers often emit.

The firſt phyſician who formed an opinion of the ſalutary qualities of fixed air, was, I think, the late Dr. Macbride of Dublin. His opinion was formed very much on the theoretical views which I mentioned lately. Dr. Percival of Mancheſter eſteems fixed air highly medicinal in pulmonic conſumptions, and in malignant fevers. The happieſt effects have been experienced from the uſe of it, both external and internal; and he ſays that he does not know a more powerful remedy for foul ulcers, as it mitigates pain, promotes a good digeſtion of the ſore, and corrects the putrid diſpoſition of the fluids. He thought that he had reaſon to infer from ſeveral experiments that water with fixed air is a ſolvent of the urinary calculus, and that the urine of a perſon who drinks plentifully of ſuch water becomes ſtrongly impregnated with the fixed air, and diſſolves the calculus. Some calculi are beſt diſſolved by alkalis, others by acids; but fixed air acts on them all.

The late Dr. Dobſon of Liverpool, afterwards of Bath, has publiſhed a number of caſes in which he found it very uſeful and ſalutary; particularly, in putrid fevers, in the cure of ill-conditioned ulcers, and in certain relaxed and debilitated ſtates of the ſtomach, occaſioning want of appetite and indigeſtion. But he did not find it effectual in relieving ſymptoms of the ſtone and gravel; though it proved often uſeful in ulceration of the organs.

The *aqua acalina aërata* is certainly an excellent medicine in calculous caſes,—not as a ſolvent, but as a moſt effectual palliative, aſcertained by experience. I know no ſolvent to be relied on. Cauſtic alkali is very powerful; but, that it may not act on the bladder itſelf, it muſt be ſo employed, that its action on the calculus is very ſlow; and the patient is fatigued and tires. The aërated alkaline water continues agreeable.

I have now conſidered, at as great length as was proper, the properties of fixed air, conſidered as an object of chemiſtry, and have taken notice of its natural hiſtory, or the forms in which we meet with it, and alſo of the many ſources from which it may be obtained by art. But there remain ſome obſervations on it, from which we are led to aſſign it a more remote origin, ſhewing it to be itſelf a compound ſubſtance. Soon after, its properties and particular nature were fully made known by the gentlemen who occupied themſelves ſo ſeriouſly with this diſcovery of mine, various opinions were formed as to its real origin. All theſe opinions were connected with the belief of the exiſtence of a phlogiſton ; and, in one way or another, I believe all of them conſidered fixed air as an emanation from inflammable bodies, or as a compound of air with their inflammable principle, or ſomething containing it. This was almoſt an unavoidable inference from our obſerving that all fuel, and inflammable ſubſtances commonly employed for producing a burning heat, when burned in air, produce a great quantity of fixed air, and diminiſh the quantity of air in which they burn ; and as all fixed air appeared to be of the ſame nature, phlogiſtication appeared the only way of producing it from ſuch a variety of bodies.

But it was afterwards found that ſome bodies, not familiar indeed as fuel, or ever employed as ſuch, yet which burn with great vivacity, ſpoil the air, making it lethal, and unfit for maintaining flame, yet void of the acid quality of fixed air, without attraction for alkalis or calcareous earth, and cauſing no precipitation of lime from lime-water. This is the caſe with ſulphur, with phoſphorus, with zinc, and ſome other metals, which we know burn like a bit of charcoal, or even with flame.

This was, I think, the firſt obſervation that made any change in the opinions formed on this ſubject, and cauſed the chemiſts to ſeek for the circumſtance of reſemblance among all the fuels whoſe combuſtion produced fixed air. I cannot ſay who was the firſt who obſerved that all ſuch fuels will be changed, in one way or another, by

great heats in close vessels, into what we call charcoal *. This is the case with all animal and vegetable substances in their natural state. Careful observation, and a well conducted chemical analysis, shew this to be equally true with respect to all the substances which art can any how extract from them, or form by mixing them. Even spirit of wine and æther, when properly treated, afford charcoal. One simple mode of treatment will have this effect on all. This is to mix them with vitriolic acid, so as to force them to stand a strong red heat along with it. Sulphurous acid is always produced, and sometimes real sulphur; but, at the same time, there is a black residuum in the retort, which is found a perfect charcoal. I believe it was among the French chemists who were associated with Mr. Lavoisier in his ingenious investigations, that the universality of this fact was first observed.

All such fuels produce fixed air by their combustion. Vegetable and animal substances alone are subject to the vinous and putrescent fermentations which emit fixed air. Charcoal seems the only common principle among them, distinguishing them from other combustible bodies. It was, therefore, a natural inference that charcoal is the primitive source of fixed air. Accordingly Mr. Lavoisier assumes charcoal for the radical or characteristic ingredient of this acid gas. But as common charcoal, from whatever substance we obtain it, contains an earthy uninflammable part, Mr. Lavoisier desires it to be understood, that it is the pure inflammable part only that he considers as the radical of fixed air; and, to distinguish this from any compound, he uses the word CARBONE. He considers fixed air, therefore, as a compound of oxygen and carbone, in the same manner as the vitriolic acid is considered by him as compounded of oxygen and sulphur. And, as he calls this the sulphuric acid, he calls fixed air the CARBONIC ACID.

* Dr. Hooke says this in many parts of his Cutlerian Lectures. EDITOR.

Mr. Lavoiſier has made ſome very ingenious experiments, which ſeem to demonſtrate this compoſition. He burned ſmall quantities of charcoal in pure oxygen gas, in cloſe veſſels, and he found that a part of this gas was converted into fixed air. He ſeparated this from the reſt of the oxygen by means of cauſtic alkali, and weighed the alkali after it had attracted the fixed air. He alſo expelled the air again by an acid, and examined its bulk. Thus he learned the weight of the air, and what meaſure of it had been produced. Then, comparing this weight with that loſt by the charcoal which had been conſumed, he found it to exceed greatly the weight of the charcoal, and was exactly equal to the weight of the charcoal and of that portion of the oxygen gas which had been changed into fixed air. He found that 100 grains of carbonic acid contained 72 grains of oxygen gas and 28 grains of carbone. This compoſition, and this proportion of the ingredients, have been confirmed by many other direct experiments of the ſame kind; and they agree ſurpriſingly with the reſults of more complicated experiments, in which this proportion is taken for granted in the explanation of other phenomena. I therefore readily adopt his denomination of carbonic acid as extremely proper, indicating the nature of the ſubſtance.

It appears then, from ſome experiments which have been mentioned occaſionally, that this carbonaceous matter is ſeparated and thrown off from the blood in the lungs in the act of reſpiration: For air that has been breathed always contains carbonic acid. In proportion to the quantity of this acid which air contains, it is deficient in its due proportion of free oxygen gas, a part of it having been changed into carbonic acid, by meeting with carbone in the lungs. This has been aſcertained by the experiments of Scheele, Lavoiſier, Dr. Goodwin, and Dr. Menzies; which two laſt gentlemen have publiſhed good experiments on this ſubject in their inaugural diſſertations.

You will, therefore, eaſily underſtand what happens when atmoſpherical air paſſes through burning fuel. The oxygenous part of

that air, and the carbone of ſome of the charcoal, unite and form a quantity of carbonic acid; and, when the air ariſes from burning fuel, inſtead of being a mixture of foul air and oxygen gas, as it was before, it is now a mixture of this foul air, carbonic acid, and the remainder of oxygen gas, which has not yet been ſaturated with carbone, but would become ſaturated by a ſomewhat longer and more effectual application of the one to the other. The heat, which is produced in great quantity on this occaſion, is ſuppoſed to have come chiefly from the oxygen gas, which, becoming more denſe, and having its capacity for heat diminiſhed by this condenſation, muſt throw out a conſiderable portion of heat which it previouſly contained, and along with the heat a quantity of light, which is perhaps the ſame matter, acting or modified in a different manner *.

Other names have been given to this fluid by the many chemiſts who were occupied on theſe ſubjects. I called it fixed air, becauſe it was found by me fixed in a number of ſubſtances. Mr. Cavendiſh changed this name to fixable air. Many preferred the name gas, and called it acidulous gas. Mr. Henry of Mancheſter, and Profeſſor Bergmann, called it the aërial acid. Mr. Fourcroy called it *acide crayeux*,—acid of chalk; but all ſeem now agreed in giving it the ſcientific name carbonic acid.

In conformity with the general plan of their reformed chemical language, the French chemiſts have named the compounds which contain this acid *carbonats*. Thus, chalk or limeſtone is the *carbonat*

* This Lavoiſierian theory of the combuſtion of charcoal is preciſely the ſame with that publiſhed by Dr. Hooke in his Micrographia, in 1664-5, (page 103), as a general theory of combuſtion. All combuſtion is, according to him, the ſolution of what we call the combuſtible body in the pure nitro-aërial ſpirit which makes part of the atmoſphere. In the caſe of certain bodies, there is not only no incombuſtible or recrementitious matter, but the compound itſelf is volatile, and is diſperſed in the air. The great heat proceeds entirely from the nitro-aërial ſpirit; and the light is the vibratory pulſe produced in the æther, whoſe undulations produce in us the ſenſation of light.

EDITOR.

of lime; mild vegetable alkali is the *carbonat of potaſh;* mild foſſil alkali is the *carbonat of ſoda;* crude magneſia the *carbonat of magneſia;* and mild volatile alkali the *carbonat of ammonia*, &c.

Thus, gentlemen, have I thrown together the chief diſcoveries which have been made concerning the nature and chemical properties of the elaſtic fluid which I diſcovered in 1756. Theſe diſcoveries have been made at very different times, and by many different authors. For the public attention continued for a long while to be very much turned to this ſubſtance, which comes ſo often in our way in chemical proceſſes, and alſo in the great operations of nature. The curioſity of philoſophers being thus turned to a very novel kind of object, an elaſtic fluid, this gave riſe to a new kind of manipulation, and a new apparatus, and a manner of management equally novel,—all which made it give much entertainment. And in this new path a number of other objects of the ſame uncommon kind came in their way, and increaſed the intereſt taken in the ſtudy. Curious chemiſts even tried to produce new airs, as they were called, by every poſſible means, in expectation of ſingular reſults and diſcoveries: And thus has ariſen a quite new ſpecies of chemiſtry, which may be called PNEUMATIC CHEMISTRY, becauſe occupied in the ſtudy of fluids permanently elaſtic, like air. In the proſecution of theſe inveſtigations, chemical apparatus was greatly improved; and we can now manage thoſe ſlippery ſubſtances as eaſily as we formerly managed the ſolids and liquids in our ordinary veſſels. The boundaries of chemiſtry have been wonderfully enlarged, and diſcoveries have been made of the moſt unexpected nature. Common water, which, from the dawn of natural ſcience, has been conſidered as an unchangeable element, is now found to be a compound of two kinds of air. Diamond, ſeemingly the pureſt and moſt unchangeable of things, is now found to be coal. And all our former notions of chemical relations are now changed.

Among theſe new chemiſts, Dr. Prieſtley is certainly one of the moſt

eminent. He was one of the firſt in reſpect of time; and he has ſurpaſſed them all in the number and variety of his experiments, and I may add, in his diſcoveries. Dr. Prieſtley firſt narrated a number of experiments on fixed air and ſome other elaſtic fluids, in ſeveral ſucceeding volumes of the Philoſophical Tranſactions in 1772, &c. and then publiſhed them in ſeveral ſeparate volumes. The elaſtic fluids which engaged his attention were, *1ſt, Fixed Air.* *2d, Atmoſpheric Air*, in its ordinary ſtate, and as changed or vitiated for the purpoſes of life by various means. *3d*, What he called *Marine Acid Air*, which is nothing elſe than the incoercible vapours of pure muriatic acid without water to condenſe it. *4th*, The incoercible vapours of the ſuffocating ſulphurous acid, named by him *Vitriolic Acid Air.* *5th*, The incoercible vapours of pure volatile alkali, which he calls *Alkaline Air.* *6th*, The highly inflammable elaſtic fluid which we have long known by the name of *Inflammable Air.* *7th*, The incoercible vapours which eſcape from a ſolution of metals in nitrous acid, which he calls *Nitrous Air.* *8th*, That ſurpriſing ſort of air in which inflammable ſubſtances burn with extraordinary rapidity and brightneſs, and which ſupports animal life and flame four or five times better than common air. This he called *Dephlogiſticated Air.* In giving the name air to ſome of theſe elaſtic fluids, he followed the practice of others. But he was the firſt who applied this term to them all. He has not been followed in this practice by many chemiſts. The moſt general practice has been, to denominate all permanently elaſtic fluids, except air, gas,—a name firſt given by Van Helmont to the vapour which is emitted by fluids in the vinous fermentation *.

* This is probably a latiniſation of *gæſcht*, a vulgar word for leaven, whence we have our word yeaſt: It is likely derived from *gahren*, to ferment. Van Helmont calls the vapour emitted by fermenting liquors, *gas ſilveſtre*, an epithet borrowed from Paracelſus, who calls it *ſpiritus ſilveſtris.* Van Helmont conſiders this as of the ſame kind with that of the Grotto del Cane in Italy, becauſe both kill breathing animals and extinguiſh flame. He mentions, however, ſeveral ſuch vapours which he conſiders as of a different nature, —*gas ventoſum*,—*flammeum*,—*pingue*, &c.; and he ſays, that theſe gaſes do not exiſt in

Dr. Prieſtley's writings contain the deſcription of various and very curious experiments, by applying water and many other ſubſtances to theſe airs; by expoſing in them living animals and vegetables, or animal and vegetable ſubſtances under the vinous, acetous, or putreſcent fermentation; by burning bodies, or by calcining or reducing metals in them; or by mixing the different airs together, and treating the mixtures with great heats, or the electrical ſpark, &c. He notices many properties of the air which we have been ſo minutely conſidering; but I ſuſpect that he has not good authority for ſome of his notions on this ſubject. He has made many ſurpriſing diſcoveries; but his experiments are ſo numerous, and the ſucceſſion in which they were made and publiſhed is ſuch, that no general account can be given of them. It will be better for you to read his own accounts of them, when you are farther advanced in this courſe: For you muſt be acquainted with a great many more chemical ſubſtances and general facts, before you can peruſe Dr. Prieſtley's writings ſo as to underſtand them. I ſhall have occaſion, in the reſt of this courſe, to notice the greateſt part of his leading experiments and diſcoveries.

Soon after Dr. Prieſtley, or much about the ſame time, the late Mr. Lavoiſier in France, a gentleman diſtinguiſhed for his love of ſcience, and particularly of chemiſtry, eminent alſo for a penetrating genius, ſound judgment, and logical accuracy; and having an ample fortune, which enabled him to execute the moſt extenſive and coſtly experiments,—this gentleman, I ſay, made and publiſhed experiments on this very ſubject. He began, by repeating with ſcrupulous exactneſs, and on a large ſcale, and with fine inſtruments, the experiments al-

their elaſtic form in the bodies from which they proceed,—nor indeed exiſt at all in them, but ariſe from new combinations of the ingredients, which cannot exiſt in a ſolid or liquid form, but which required particular circumſtances to change their former combinations, and enable the ingredients to form theſe new ones. His notions on this ſubject are wonderfully ſagacious, and even preciſe, conſidering the time in which he wrote, when vague and indiſtinct conceptions ſeemed to be more generally acceptable. (See his *Complexionum atque Mixtionum elementarium Figmentum.*) EDITOR.

ready made by others. But he afterwards puſhed on his inveſtigations much farther, and made ſome deciſive experiments, which led him to great diſcoveries and enabled him to explain many general phenomena of nature, and to compoſe a new ſyſtem or theory exceedingly ingenious and ably ſupported by numerous and convincing experiments. This theory has changed the whole face of chemiſtry. I ſhall have an opportunity very ſoon to take further notice of the outlines at leaſt of this new chemical philoſophy.

While Dr. Prieſtley in England, and others elſewhere, were attending to theſe objects, Dr. Scheele of Sweden, whom I formerly had occaſion to mention, engaged in an inquiry into the nature of fire and light and heat; and, without any knowledge of what was done and doing by others, carried on a moſt ingenious inveſtigation, in which he was led, by the train of his reſearches, to make many of the experiments and diſcoveries already made by theſe gentlemen. He added many of his own. His work has been tranſlated, but very badly indeed, by J. Rheinhold Foſter, and is entitled, "Scheele on Fire."

Among the remarkable diſcoveries which theſe experiments on gaſes have produced, perhaps the chief is that of VITAL AIR, by Dr. Prieſtley. It is this, in combination with Lavoiſier's theory of combuſtion, that has totally changed our notions of the chemical relations of moſt ſubſtances, and made a revolution in all the leading doctrines of chemiſtry. I have already taken notice of its remarkable property, when we were conſidering the decompoſition of nitre, in order to obtain its acid. We ſhall meet with it again, almoſt at every ſtep; and its various chemical relations will be diſcovered as we proceed.

Scarcely inferior to vital air in chemical importance is the *faul air* of Dr. Scheele, which I mentioned on the ſame occaſion, as that noxious portion of atmoſpherical air which remains when the vital air has been abſorbed by the *hepar ſulphuris*. I muſt here obſerve, that this portion of our atmoſphere was firſt obſerved in

1772 by my colleague Dr. Rutherford, and publiſhed by him in his inaugural diſſertation. He had then diſcovered that we were miſtaken in ſuppoſing that all noxious air was the fixed air which I had diſcovered. He ſays, that after this has been removed by cauſtic alkali or lime, a very large proportion of the air remains, which extinguiſhes life and flame in an inſtant.

Soon after this, Dr. Prieſtley met with this noxious air, which was produced in a variety of experiments, in which bodies were burned, or putrefied, or thickened in certain caſes, or metals calcined, or minerals effloreſced, &c. &c. In all theſe caſes, he thought that he had reaſon to believe that phlogiſton had quitted the ſubſtances under conſideration,—had combined with the air,—and had thus vitiated it. Now ſaturated with phlogiſton, the air could take no more, and therefore extinguiſhed flame. He called all theſe proceſſes *phlogiſticating proceſſes*, and the air thus tainted *phlogiſticated air*.

In theſe proceſſes the air was not only ſpoiled, but alſo diminiſhed in bulk. This had been obſerved long before by Boyle and Hales. They aſcribed this to a diminution of its elaſticity. Dr. Prieſtley aſcribed it to the precipitation of fixed air. Mr. Cavendiſh aſcribed it to the combination of ſome of its ingredients in ſuch a manner as to form water. His celebrated experiment, by which he demonſtrated the compoſition of water, will be mentioned particularly in another place.

Dr. Scheele chanced to take a very different view of the whole of this ſubject,—led to his ſingular notion of it by ſome preconceived and very ſtrange theory of fire and heat. But Scheele found that this diminution of bulk was owing to a real abſtraction of all the vital air which the atmoſpheric air contained. For when any of theſe phlogiſticating proceſſes of Dr. Prieſtley were performed in vital air, it was *totally* abſorbed. The remainder therefore, when the experiment was made in common air, was conſidered by him as a primitive air, unchanged in its properties. He called it *foul air*, which

may mean either *rotten* air, becauſe it is produced in vaſt abundance by putrefying bodies, or ſimply *foul air*, i. e. tainted occaſionally, when the phlogiſton is more than will ſaturate the vital air. When he burned phoſphorus in atmoſpheric air, he found the remaining noxious air free from all admixture.

Mr. Berthollet obtained this faul air, not only from animal and vegetable ſubſtances in the putrefactive fermentation, but alſo in great abundance, by pouring nitric acid on the freſh muſcular fibre. Fourcroy found that it was contained almoſt pure in the ſwimming bladders of carp, bream, and other fiſhes. Other chemiſts have found it in volatile alkali, as will be particularly noticed afterwards.

In all theſe methods of procuring it, it muſt be cleared from fixed air by means of lime or cauſtic ley.

This air, having been procured in ſo many different ways, appeared in different lights to the diſcoverers, as you have ſeen, and got different names,—phlogiſticated,—foul,—mephitic,—choke-damp (in German), &c. Mr. Chaptal, and other chemiſts of the firſt rank, gave it ſtill another, and perhaps more proper name, calling it *nitrogen*. This took its riſe from a celebrated diſcovery of Mr. Cavendiſh, recorded in the Philoſophical Tranſactions of 1783. A train of experiments, begun ſeveral years before, ended in his combining ſeven parts of oxygen and three of this air, by means of repeated diſcharges of electricity. The mixture was wholly abſorbed by a ſolution of potaſh, and *formed perfect nitre*. Therefore, he concluded that this proportion of theſe two airs compoſe that remarkable ſubſtance, nitrous acid. Hence theſe gentlemen called this gas nitrogen, with as much propriety as inflammable air was called hydrogen. But Mr. Lavoiſier, after having repeated the experiment of Cavendiſh with complete ſucceſs, and after being convinced, by the compariſon of numberleſs facts, and particularly, after reflecting on all the proceſſes for producing ſaltpetre, all of which employ animal and vegetable ſubſtances in a ſtate of putreſcence, in the free air,—after this full conviction that this was really the

compoſition of nitrous acid, rejected the appellation of nitrogen, and called it Azotic Gas, from its deletereous quality. This denomination has taken place of all others; and I ſhall abide by it in the reſt of the courſe, although I think that a better name might have been found than this, which really is no diſtinction, becauſe all the gaſes are azotic, that is, deadly to breathing animals, except thoſe which contain a very great proportion of oxygen gas, or vital air. *(See Note 3. at the end of the Volume.)*

In the mean time, this diſcovery by Mr. Cavendiſh is one of the moſt important in the whole ſcience of chemiſtry. I mean, the diſcovery that Azote is the radical or characteriſtic ingredient of the nitrous acid. I have given you only that ſimple fact, by which the truth of this doctrine was eſtabliſhed by that gentleman. Numberleſs proofs, both by compoſition and decompoſition, will come before us, as we proceed in the examination of other bodies. I only remark at preſent, that the proportion of ingredients, in the experiment of Mr. Cavendiſh, correſponds to the moſt fuming ſtate of the acid that can be prepared. It is even redundant in azote, which the nature of the experiment did not permit Mr. Cavendiſh to obſerve. The acids are ſuſceptible of different proportions of oxygen, as we ſhall afterwards ſee clearly; and, in theſe different ſtates, they are permanent, and have very diſtinct properties and modes of action. None of them is ſo remarkable in this reſpect as the nitric acid; and the knowledge of its diſtinctions will lead us through the moſt intricate paths of the inveſtigation yet before us,—ſo that it is with great juſtice that I have ſaid that this diſcovery by Mr. Cavendiſh is one of the moſt important in the ſcience.

In nitric acid, which is its moſt perfect ſtate as an acid, the proportion of oxygen to azote is nearly that of 80 to 20. Nitrous acid, or *ſpiritus nitri fumans Glauberi*, has that of 75 to 25. Nitrous gas, which eſcapes from nitrous acid when inflammable ſubſtances are mixed with it, has the proportion 68 to 32 nearly. But this is ſcarcely, if at

all acid. You will learn all this by degrees, when you previouſly know the nature of the ſubſtances mixed with the perfect acid.

With reſpect to the other properties of azote, I cannot ſay much at preſent, becauſe you know as yet but few of the ſubſtances to which thoſe properties relate.

It is rarer than common air, about $\frac{1}{18}$th. The ſpecific gravities of atmoſpheric air, oxygenous gas, and azotic gas, are 1,0000, 1,0625, and 0,9444*.

Azotic gas does not mix with water.

It has no acidity; it does not affect the ordinary teſt colours, nor contract any union with alkaline ſubſtances; therefore it does not precipitate lime from lime-water.

Although it combines with oxygen by means of the electric ſpark, and compoſes nitrous acid, and although there is always this mixture in the air, we do not find nitrous acid there. Theſe gaſes are ſuſceptible of ſimple commixtion, as water mixes with ſpirits, or one metal with another, yet they retain their properties unchanged, like the mixtures now mentioned. It is not ſimply a high temperature that will cauſe them to combine, for they do not combine when forced through a red hot tube of glaſs. *(See Note 4. at the end of the Volume.)*

I have been led into this long digreſſion by the experiments adduced in ſupport of the third propoſition of my theory of lime. Theſe gave me an opportunity of explaining to you, by means of the acquaintance which you have already acquired with ſeveral chemical ſubſtances, the properties of the three remarkable gaſes,—fixed air, vital air, and foul air; or, as I ſhall now call them, carbonic acid gas, oxy-

* A thouſand cubic inches, or a box, whoſe length, breadth, and depth is 10 inches, contains, in the ordinary preſſure of the atmoſphere, and temperature 55° of Fahrenheit, very nearly the following quantities:

Common air	315 grains Troy.	One inch =	0,315
Oxygenous gas	335		0,335
Azotic gas	297		0,297

EDITOR.

genous gas, and azotic gas. The knowledge of their leading properties will greatly expedite our progreſs through the reſt of this courſe. I now return to the theory of quicklime.

The experiments made to try the fourth and fifth propoſitions were found to agree equally well with the theory. Several of them concurred, in the firſt place, to ſhew that the cauſtic alkalis do not contain any lime or limy matter combined with them. I ſatisfied myſelf of this by three trials: 1*ſt*, Evaporation to dryneſs, and examination of the dry cauſtic alkali. 2*d*, Saturation with ſulphuric acid. This, if there be any lime, ſhould produce a ſelenite almoſt inſoluble in water. I found none. I obſerve ſome experiments of others in which a precipitate was obſerved; but, by the very account given, it appears to have been vitriolated tartar, which a large quantity of hot water would have diſſolved. 3*d*, Expoſition to the atmoſphere, to learn whether cruſts of calcareous earth would be formed on its ſurface, like thoſe on lime-water. But no ſuch thing appeared. All theſe trials verified the fourth propoſition, ſhewing that cauſtic alkalis contain no lime.

And in my experiments relative to the fifth propoſition, I ſucceeded perfectly in changing the calcareous earth into lime, without expoſing it to the action of heat. The precipitate from a muriate of lime by a truly cauſtic alkali proved a perfect quicklime, diſſolving completely in water, and making lime-water.

It now appears that by whatever way we contrive to ſeparate the carbonic acid from calcareous earth, even without making uſe of fire, the earth is thereby rendered active, and appears in the ſtate of acrid and ſoluble lime. We have, therefore, abundance of reaſon to conclude, that the ſtate of ſolubility and activity of this earth depend on its being ſimply reduced to a ſtate of purity, or freed from the carbonic acid which it is combined with in its natural ſtate. The ſame

concluſion muſt alſo be admitted with reſpect to the volatile alkali, when we conſider the proceſſes by which it is made to appear in its cauſtic or moſt active form. The particular nature of this alkali enables us to deprive it of its carbonic acid, or make it free of it, by a greater variety of methods than can be followed with either of the fixed alkalis, or with quicklime. And, whatever way we take to free it from this acid, we are ſure to find it cauſtic, or in its liquid, or its highly acrid and volatile form. The common way of obtaining it is by decompoſing ſal ammoniac by quicklime. In the ammoniacal ſalt it has no carbonic acid. It is plain that it muſt alſo be obtained in the ſame ſtate, for the ſame reaſon, if the ſal ammoniac be decompoſed by the action of a cauſtic fixed alkali. Accordingly, in this way alſo are we ſure to have the volatile alkali in a cauſtic ſtate. But what may appear the moſt ſatisfactory, is a way diſcovered by Mr. Margraaf for obtaining a volatile alkali from an ammoniacal ſalt by heat alone,—namely, from the eſſential ſalt of urine, or microcoſmic ſalt. This ſalt is an ammoniacal ſalt, at leaſt in part, or contains the volatile alkali, which may be ſeparated, as from other ammoniacal ſalts, by either fixed alkali or by quicklime: And, in theſe caſes, we obtain the volatile alkali in the ſame ſtate as we would obtain it by the ſame proceſſes from other ammoniacal ſalts. But Mr. Margraaf diſcovered that the ſal microcoſmi will yield its volatile alkali by the action of heat alone, becauſe the acid is of the moſt fixed kind. He put ſome of this ſalt into a retort, and fitted to it a receiver having a ſmall perforation. There firſt of all eſcaped ſome incondenſible matters with which we are now pretty well acquainted. Theſe were followed by the volatile alkali in a moſt pungent ſtate. Some of it condenſed with water in the receiver; and he was ſurpriſed to find that it did not effervesce with acids.

There is, therefore, no doubt that if we could ſeparate the fixed alkali from an acid by an operation as ſimple, we ſhould have it alſo in a cauſtic form; but I am not acquainted with any inſtance of ſuch

ſeparation in chemiſtry. There are two which might at firſt ſight appear of this kind. The firſt is the ſeparation of the fixed alkali from nitric acid by deflagration with charcoal; and the ſecond, its ſeparation from the vegetable acid merely by heat. But in neither of theſe caſes is the alkali obtained free from carbonic acid. On the contrary, it contains a good quantity of it, and is diſpoſed to effervesce ſtrongly with acids. And the reaſon is, that in the firſt caſe the nitric acid and the charcoal, in acting upon one another, produce a great quantity of carbonic acid, of which a part, it ſeems, is attracted by the alkali. It is eaſy to underſtand how this carbonic acid is produced. It is produced from the charcoal, and the vital air which the nitre affords in very great quantity when expoſed to the action of red heat. And, in the ſecond caſe, the acetous acid is not ſimply ſeparated. It is deſtroyed by the fire, and converted into water, oil, charcoal, and a large quantity of carbonic acid, which, together with the charcoal, is found adhering to the fixed alkali *.

In every caſe, therefore, in which we contrive to have lime or the alkaline ſalts in a pure ſtate, or free from carbonic acid, we find them in their ſtate of greateſt activity, or cauſticity as it was formerly termed. And if we examine the converſe of theſe experiments, and conſider the different ways by which quicklime or the cauſtic alkalis may be rendered mild, we ſhall find that their return to a mild ſtate is always attended with the recovery of their carbonic acid, and is evidently a conſequence of it.

One example of this is the reſtoration of the cauſtic volatile alkali to its milder ſtate, by an experiment which I made in the year 1757 or 1758, and communicated, with ſome others, to my friend Dr. Hutcheſon, of Trinity College, Dublin, and which has been publiſhed by Dr. Macbride in his Eſſays, page 50. A ſmall quantity of cauſtic alkali is put into a phial. In another phial an effervesing

* Nitre deflagrated with zinc gives cauſtic alkali. EDITOR.

mixture is put; and the fixed air expelled from it is made to paſs through a ſyphon tube fixed into its mouth, and having the other leg inſerted into the cauſtic alkali. By this ſimple apparatus, the fixed air is made to riſe through the alkali, which rapidly abſorbs part of it, and ſoon acquires ſo much as to effervеſce briſkly with acids. If a bladder, fitted up like a common medical injection bladder, with a pipe and a cork, be diſtended with fixed air, and the pipe (having put in the cork) be now inſerted into the phial containing the cauſtic alkali, and if the pipe fit the mouth of this phial, ſo as not to allow air to get paſt it, then, on pulling out the cork, the compreſſed fixed air will be forced in among the alkali, and will be gradually abſorbed by it, and we ſhall ſee the bladder collapſe by degrees, till perhaps all be abſorbed. The alkali will now effervеſce with acids. The pure fixed alkalis are alſo eaſily reſtored to a mild effervеſcent ſtate by the ſame proceſs. They abſorb the carbonic acid gas very quickly, even more quickly than milk of lime; not becauſe they have a ſtronger attraction for it than lime has, (for the contrary is the fact) but becauſe we can employ a much ſtronger ſolution of theſe alkalis than the ſolution we have of lime in lime-water.

It is ſcarcely neceſſary to remark that the cauſtic fixed alkalis become mild alſo by communication with the atmoſphere for a ſufficient length of time, and that when they become mild in this way, it is by attracting carbonic acid. This happens more quickly than ordinary, when ſolutions of them are boiled over an open fire; the reaſon of which you will eaſily perceive to be the quantity of carbonic acid which is inceſſantly forming by the conſumption of the fuel.

They are rendered mild alſo by adding to them a proper quantity of magneſia, that has not been calcined, (now named carbonat of magneſia) or a proper quantity of common mild volatile alkali (the carbonat of ammonia); the fixed alkalis having a ſtronger at-

traction for the carbonic acid than either of theſe two alkaline ſubſtances; of which I aſſured myſelf by direct and concluſive experiments.

From the knowledge we now have of the efferveſcence of alkaline ſalts with acids, it is eaſy to explain the very remarkable manner in which the vegetable alkali, in its ordinary ſtate, efferveſces with ſome of the weaker acids, of which you ſaw an example, when the acetite of potaſh was deſcribed, and the proceſs for preparing it.

The ſame phenomenon occurred to me alſo when I tried to make a borat of potaſh by ſaturating the common alkalis with ſedative ſalt.

Borax has ſometimes been referred to the claſs of alkalis, on account of ſome reſemblance it bears to thoſe ſalts: But it has been demonſtrated by accurate experiments, that we ſhould rather conſider it as a neutral ſalt; that it is compoſed of an alkali, and of a particular ſaline ſubſtance, called the ſedative ſalt, which adheres to the alkali in the ſame manner as an acid, but can be ſeparated by the addition of any acid whatever, the added acid joining itſelf to the alkali in place of the ſedative ſalt. As this conjunction of an acid with the alkali of borax happens without the leaſt efferveſcence, our principles lay us under a neceſſity of allowing that alkali to be perfectly free of air, which muſt proceed from its being incapable of union with fixed air, and with the ſedative ſalt, at the ſame time: Whence it follows, that were we to mix the ſedative ſalt with an alkali ſaturated with air, the air would immediately be expelled, or the two ſalts, in joining, would produce an efferveſcence. This I found to be really the caſe, upon making the trial, by mixing a ſmall quantity of the ſedative ſalt with an equal quantity of each of the three alkalis, rubbing the mixtures well in a mortar, and adding a little water. It is, however, proper in this place to obſerve, that if the experiments be made in a different manner, they are attended with a ſingular circumſtance. If a ſmall quantity of the ſedative

ſalt be thrown into a large proportion of a diſſolved fixed alkali, the ſedative ſalt gradually diſappears, and is united to the alkali without any efferveſcence; but, if the addition be repeated ſeveral times, it will at laſt be accompanied with a briſk efferveſcence, which will become more and more remarkable, until the alkali be entirely ſaturated with the ſedative ſalt.

This phenomenon may be explained by conſidering the fixed alkalis as not perfectly ſaturated with air; and the ſuppoſition will appear very reaſonable, when we recollect that thoſe ſalts are never produced without a conſiderable degree of heat, which may eaſily be imagined to diſſipate a ſmall portion of ſo volatile a body as air. Now, if a ſmall quantity of the ſedative ſalt be thrown into an alkaline liquor, as it is very ſlowly diſſolved by water, its particles are very gradually mixed with the atoms of the alkali. They are moſt ſtrongly attracted by ſuch of thoſe atoms as are deſtitute of air, and therefore join with them without producing an efferveſcence; or, if they expel a ſmall quantity of air from ſome of the ſalt, this air is at the ſame time abſorbed by ſuch of the contiguous particles of it as are deſtitute of it; and no efferveſcence appears, until that part of the alkali which was in a cauſtic form, or deſtitute of air, be nearly ſaturated with the ſedative ſalt. But if, on the other hand, a large proportion of the ſedative ſalt be perfectly and ſuddenly mixed with the alkali, the whole, or a large part of the air, is as ſuddenly expelled.

In the ſame manner, we may alſo explain a ſimilar phenomenon, which often preſents itſelf in ſaturating an alkali with the different acids. The efferveſcence is leſs conſiderable in the firſt additions of acid, and becomes more violent as the mixture approaches the point of ſaturation. This appears moſt evidently in making the ſal diureticus, or regenerated tartar. The particles of the vegetable acid here employed, being always diffuſed through a large quantity of water, are more gradually applied to thoſe of the alkali; and, during the firſt additions, are chiefly united to thoſe that are freeſt of air.

But ſtill this explication reſted on a ſuppoſitio , and there was no neceſſity for letting it reſt there. It was eaſy to try whether this ſuppoſition was agreeable to truth by an experiment.

I expoſed a ſmall quantity of a pure vegetable fixed alkali to the air, in a broad and ſhallow veſſel, for the ſpace of two months, after which I found a number of ſolid cryſtals, which reſembled a neutral ſalt ſo much, as to retain their form pretty well in the air, and to produce a conſiderable degree of cold when diſſolved in water. Their taſte was much milder than that of ordinary ſalt of tartar; and yet they ſeemed to be compoſed only of the alkali, and of a larger quantity of air than is uſually contained in that ſalt, and which had been attracted from the atmoſphere; for they ſtill joined very readily with any acid, but with a more violent effervescence than ordinary; and they could not be mixed with the ſmalleſt portion of vinegar, or of the ſedative ſalt, without emitting a ſenſible quantity of air.

Thus, therefore, I learned that the fixed alkali, in the ordinary ſtate of it, is never completely ſaturated with carbonic acid, or combined with the largeſt quantity of it which it is capable of receiving. And further experiments on this and the other alkalis ſhewed that they contained more or leſs of it according to the proceſs by which they have been prepared, or the treatment they have undergone in preparing them; but that they may be all completely ſaturated by different methods, eſpecially by expoſing them to the gas of fermenting liquors, or to the gas expelled from chalk by the ſulphuric acid. As they are uſually prepared, I believe the mildeſt or moſt nearly ſaturated with fixed air, is that called black flux, which is tartar no farther burnt than to deſtroy the acid, and intimately mixed with charry matter, from which it may be obtained pure by lixiviation. The chemiſts of laſt century, or rather the pharmaciſts, mention a general claſs of alkaline ſalts by the name of ſalts of Tachenius, which were remarkably mild (in a medical ſenſe). By the account given of their preparation, they muſt have been mild in the ſenſe which I have af-

fixed to the term. They were prepared from vegetables by a ſmothering heat, which did little more than char the plant, and muſt therefore have retained a great portion of carbonic acid. Pearl-aſhes comes next to black flux in ſaturation with carbonic acid. White flux comes next to pearl-aſhes, and ſhould be followed by potaſh, which is often pretty acrid by long continuance in the melting heat. Of the volatile alkalis, the mildeſt is ſurely the volatile ammoniac prepared with chalk. Next to this is ſalt of hartſhorn, tainted with much burnt oil ;—*ſpiritus cornu cervi* is more acrid,—ſo is *ſpiritus ſalis ammoniaci*, as prepared with fixed alkali.

The reſult of all this inveſtigation is, that the alkaline ſubſtances, in their mild ſtate, are to be conſidered as compound ſalts, conſiſting of the pure alkaline ſubſtances united to the carbonic acid.

As this is to be conſidered as a new acid, and muſt be added to our liſt of ſimple ſalts, we have a new column to be added to the ſix already placed in your table of compound ſalts. We muſt, therefore, ſee what is to be the arrangement of this column, having carbonic acid or fixed air at the head.

1*ſt*, then, It is evident from the whole tenor of the inveſtigation, that pure quicklime muſt be placed firſt in the column of alkaline ſubſtances. The proceſs for cauſtic fixed alkali, and the precipitation of lime from lime-water by a mild alkali in a mild ſtate, prove it in reſpect of the foſſil alkalis. That the attraction of lime for carbonic acid is greater than that of the volatile alkali, is alſo evident by the proceſs for cauſtic volatile alkali without heat, and by the precipitation of lime from lime-water in a mild ſtate by mild volatile alkali.

Lime muſt alſo come before the pure earth of magneſia, becauſe crude magneſia precipitates lime in a mild ſtate from lime-water.

2*d*, The fixed alkalis come next in order: For they will render a ſolution of volatile alkali cauſtic. Moreover, a cauſtic ley becomes mild, or will effervеſce with acids, if we put into it crude magneſia, and digeſt the mixture for a little while.

3*dly*, Magneſia comes before the volatile alkali: For cauſtic volatile alkali makes no change on crude magneſia;—but calcined magneſia will effervesce with acids after being digeſted with mild volatile alkali.

The column muſt therefore ſtand thus:

Carbonic Acid.
Quicklime.
Fixed alkali.
Magneſia.
Volatile alkali.

It remains to determine the proportion of the attractions of quicklime and magneſia, and the alkalis for the other acids.

1*ſt*, Fixed alkali has a ſtronger attraction for the other acids than quicklime has. This appears from the proceſs by which we make quicklime, by precipitating it from a ſolution in any acid by means of a cauſtic fixed alkali. We have alſo ſeen, that fixed alkali, in its pure or cauſtic ſtate, precipitates magneſia from the acids in a non-effervescent ſtate;—and we know that it diſengages the volatile alkali without heat.

2*dly*, Quicklime muſt have the next place: For we have ſeen that the precipitate by means of lime from a ſolution of magneſia was not a quicklime, but a pure non-effervescing magneſia. Alſo we found that quicklime, whether ground with ſal ammoniac in a dry powdery ſtate, or put into a ſolution of it in water, inſtantly detached the volatile alkali. It is true that a mild volatile alkali will precipitate calcareous earth from an acid. But the precipitate is a carbonat of lime, and the change has been effected by a double elective attraction, proving that the partiality of the volatile alkali for any other acid is greater than that of the quicklime. The precipitation of calcareous earth, in a mild ſtate, by carbonat of magneſia, is explained in the ſame way. The precipitate is a carbonat.

I cannot decide, by any experiment that has occurred to me, whether magneſia or volatile alkali has the ſtrongeſt attraction. I am therefore obliged to claſs theſe two ſubſtances in the ſame line of the column. And it ſtands thus:

ACIDS.

Fixed Alkali.
Quicklime.
Magneſia—Volatile Alkali.

This undetermined ſituation of magneſia and the volatile alkalis relates only to their mixture and action on each other in the ordinary low temperatures. For it is plain that if we employ great heats, the volatility of the ammonia diſpoſes it to quit the more fixed baſe to which it is joined. Magneſia, treated along with this compound, tends, by its attraction for the acid, to repreſs the volatility of the acid. This will evidently ſtill further promote the ſeparation of the volatile alkali; and thus magneſia will certainly decompoſe the ammoniacal ſalts with the aſſiſtance of heat, and diſengage the alkali, either cauſtic or mild.

I cannot better conclude this inquiry, than by mentioning ſome important conſequences which have reſulted from the diſcovery of the carbonic acid. Beſides the improvements in chemical ſcience to which it has led us, it has alſo given riſe to ſome uſeful inventions, and has enabled us to decide queſtions which occur in ſome of the moſt intereſting of the arts. We know now, that the alkalis are compound ſalts, of immenſe demand in the arts of bleaching, dying, ſoap-boiling, glaſs-making, &c. In their ordinary ſtate, we have learned that they contain a very conſiderable proportion of a ſubſtance which is of no value in thoſe arts, that we know of as yet, and which therefore diminiſhes the value of the commodity. Theſe artiſts can now aſcertain with a certain preciſion, in what degree any parcel offered to them is of uſe, and can chooſe or reject, or correct them as they ſee occaſion.

Thus, in agriculture, a queſtion is now decided which has been often put to me,—whether freſh or acrid lime is better or worſe than ſuch as has been long expoſed to the air. The effect of marles and of limeſtone gravel, which are known to be the moſt excellent of natural manures, decides this queſtion. The only uſeful purpoſes of burning limeſtone ſeems to be the reduction of its weight, and the eaſy method of reducing it to powder, and thus fitting it for being uniformly ſpread on the ground.

The value of marles is alſo eaſily aſcertained by theſe doctrines. Marles are valuable only in proportion to the calcareous matter they contain. Some do not hold $\frac{1}{20}$th of their weight; and it is a very rich marle that holds $\frac{1}{4}$th. Suppoſe a marle to contain $\frac{1}{10}$th, a farmer will conſult his intereſt if he pays ten times the price for a cart of lime that he muſt pay for marle at the ſame diſtance; for he will bring home the ſame quantity of the uſeful material with $\frac{1}{10}$th of the labour and carriage.

Now of all the modes of trial of the quantity of calcareous matter in marle, the one beſt ſuited to the unlearned farmer is, to obſerve how much fixed air it contains: And this he will learn certainly, within $\frac{1}{50}$th of the truth, by diſſolving a little of the marle in an acid, the muriatic, for example, and obſerving what portion of its weight it loſes. Thus, if any little quantity, ſuppoſe half an ounce, loſes 40 grains, he may conclude that it contained 100 grains of crude calcareous earth, or 60 grains of lime. Or he may reckon $2\frac{1}{2}$ grains of limeſtone, or $1\frac{1}{2}$ grains of lime for every grain that his marle loſes by this operation. But he muſt take care to make the trial in a deep glaſs, that ſparks of water may not be loſt, and computed for limeſtone. For the ſame reaſon, the acid muſt be weak, that the effervеſcence may be very gentle. Vinegar, however, is too weak, and will not detach all the air: It becomes clammy alſo in the operation, which makes the froth remain on the ſurface for days, and this entangles much air that has been really diſengaged. Let the acid be ſuch muriatic acid as is

fold in the ſhops. Dilute it with twice or thrice as much water, and keep it for uſe. Weigh the marle exactly, and alſo the quantity of acid which is to be poured on it, taking care that it be more than enough for diſſolving all the calcareous matter. When the ſolution is over, after repeated agitation without more effervescence, weigh the whole; the weight loſt is two-fifths of the weight of the calcareous matter.

Should we attempt to meaſure this by ſolution and precipitation, we are led into a number of examinations which will puzzle even an experienced chemiſt.

And having now finiſhed the chemical hiſtory of the calcareous earth and magneſia, I muſt take notice of ſome compounds produced by nature, in which the calcareous earth is combined with acids, and which are worthy of your attention.

CALCAREOUS EARTHS COMBINED WITH ACIDS.

Theſe compounds are, 1*ſt*, Gypſum, or the ſulphat of lime. 2*dly*, Fluor, or the fluat of lime, which is formed by a very peculiar acid not yet deſcribed. 3*dly*, Phoſphat of lime, which contains another peculiar acid not yet deſcribed. 4*thly*, Borat of lime, but lately diſcovered, which contains the ſedative ſalt; or boracic acid, combined with lime and with magneſia.

1.—*Gypſum.*

Gypsum, the moſt abundant of theſe calcareous compounds, was formerly conſidered as a peculiar ſpecies of earth; but now we are better acquainted with its nature, and are well aſſured that it is a compound of the calcareous earth with the ſulphuric acid; or is, in the new language, a Sulphat of Lime.

This compound is found in nature under ſeveral forms, or in ſeveral ſtates. The greateſt part is found in the form of ſtony maſſes,

which, however, are remarkably ſoft, ſo as to be eaſily ſcraped with a knife, or even with the nail. They are diſtinguiſhed from alkaline earths and ſtones by not effervеſcing with acids, and from all other ſtony bodies, by making ſulphat of potaſh with the mild vegetable fixed alkali, if boiled in water with this ſalt, or melted with it. When this vitriolated tartar is ſeparated by repeated waſhing with hot water, the remaining powder is found to be a mild calcareous earth. The ſame materials alſo, with the addition of charcoal duſt, form, by fuſion, a *hepar ſulphuris*, or *ſulphurat of potaſh*. Thus, the ingredients of gypſum are made ſufficiently evident. *(See Note 5. at the end of the Volume.)*

Gypſum is found in ſome places in great abundance. In the neighbourhood of Paris there are hills chiefly compoſed of it. In moſt places where it occurs, it is intermixed with a marly clay, forming ſeparate maſſes interſperſed through the ſtratum: And it is alſo ſometimes found in veins. When pure, it is white and ſemi-tranſparent in the larger maſſes, and perfectly tranſparent in its ſmall particles. The ſtructure or aggregation of theſe maſſes has ſome variety. Often ſmall cryſtalline grains are compacted together like ſugar. This is called *gypſum*, and ſometimes *alabaſter*. A ſecond kind is the *fibraria*, or fibrous gypſum, having a ſomewhat fibrous ſtructure, or being compoſed of oblong cryſtallized concretions, cloſely compacted together, which are moſtly parallel among themſelves, but lie acroſs the maſs, from the upper to the under ſurface. This ſort has varieties according to the ſize and regularity of the concretions of which it is compoſed. In ſome kinds, the concretions are larger, and more irregular in diſpoſition: In others, more ſlender and regular. A third ſpecies is that which is compoſed of clear tranſparent plates, like the fineſt glaſs, lying parallel to one another, and in cloſe coheſion through their whole extent, but eaſily ſeparable by ſplitting them aſunder with a knife. Theſe plates are exceſſively thin, or can be ſubdivided, by ſplitting into very thin ones, and have an apparent flexibility, but no elaſticity. This ſpecies is called *Glacies Mariæ*, and ſometimes, but improperly, *Muſcovy glaſs*,

or *Muſcovy talc*. A fourth appearance of this ſubſtance is in the ſtate of ſeparate cryſtals, in the forms of which there is ſome variety. They are found, I believe, in thoſe ſtrata of clay which contain gypſum in ſome of the other ſtates already deſcribed; and theſe ſeparate cryſtals were eſpecially named *ſelenites*, by naturaliſts. Fifthly and laſtly, it is very often met with in waters, in a diſſolved ſtate; for it is evidently capable of diſſolution in water, though only in very ſmall quantity, like the artificial gypſum, requiring not leſs than 500 times its weight of hot water to diſſolve it. But it can be diſſolved more plentifully, if it be acidulated with ſome ſuperfluous ſulphuric acid. It occurs diſſolved in the waters of many ſprings and wells, and is the moſt general taint of what are called hard waters; but moſt copiouſly in ſea water. When water containing gypſum is ſlowly evaporated, the gypſum ſeparates, or is depoſited in a white ſediment, which, by the microſcope, is ſeen to conſiſt of minute cryſtals like hairs.

The compoſition of gypſum was firſt clearly explained by Margraaf, in the Berlin Tranſactions. He firſt ſhewed it to be a compound of calcareous earth with vitriolic acid. And by thus knowing that it is a ſaline compound, we can more eaſily underſtand ſome of its properties.

When gypſum is expoſed to a moderate heat, it loſes its tranſparency and glittering appearance, and becomes a white opaque maſs like chalk, in which the former appearance of its ſtructure is deſtroyed. It alſo becomes very friable, rather more ſo than chalk, whatever may have been its former firmneſs. During this change, we hear a continual crackling. This muſt be conſidered as a ſort of decrepitation. If powdered firſt, and then heated, it ſwells, ſeems as if ſet afloat, and is agitated like a boiling fluid. This is occaſioned by the water being extricated from its cryſtals, which are thus deſtroyed. But after ſome time, it ſubſides into a dry powder. In cloſe veſſels it emits water, and ſome kinds of it a little ſulphurous acid. After being heated in this manner, until the bottom of the

veſſel begins to grow red, if it be then cooled, it is diſpoſed to concrete with water in a very remarkable manner. When mixed haſtily with water, to the conſiſtence of very thick cream, it remains in that ſtate without any perceptible ſubſidence. After a little while it grows ſenſibly warm; and, in a minute or two after, it is ſolid, and a little enlarged in bulk. This concretion ſeems to be a haſty and confuſed cryſtallization, or return of the gypſum to a cryſtallized ſtate, or ſtate of combination with water, which is the natural ſtate of it. In this ſtate it is extremely porous and light, when thoroughly dried, becauſe the water employed in diluting it is of more bulk than the gypſum. It is uſed for caſting figures and impreſſions of every kind, and it gives them with wonderful ſharpneſs. If one of theſe caſts, of a medal, for example, be laid on the ſurface of melted white wax with the impreſſion uppermoſt, it fills itſelf completely with the wax, and has the appearance of a piece of fine ſculpture in marble, or of a porcelain caſt.

If gypſum be expoſed to a very violent heat, it is at laſt brought into fuſion, without the ſeparation of any conſiderable part of the acid, provided, however, it be heated without touching the fuel. If it be allowed to come into contact with the fuel, a very different effect is produced. The inflammable matter of the fuel acts on the acid, and volatilizes the greater part of it, in ſuffocating vapours of ſulphurous acid and vapours of *hepar ſulphuris*. Another part remains adherent to the earth in the form of imperfect ſulphur, or ſulphurous acid, and forms with it a particular ſpecies of phoſphorus, of which hereafter. The other qualities of gypſum will be eaſily perceived from the nature of its two conſtituent parts; and it is needleſs to take notice of the action of alkalis and acids upon it.

The uſes to which it is applied are, the caſting of figures in what is called *plaſter*, or *plaſter of Paris*, and for making the moulds in which they are caſt; alſo for ornaments in *ſtucco*: And at Paris it

is much uſed in the building of houſes. In Minorca, they have a coarſe and ſtrong kind in plenty, which is employed in building. They form arches and floors of it, without needing timber to ſupport their work. It alſo has great effect as a fertilizer of land. Its effect is greateſt upon the legumina and leguminous grains. Grain, however, was not ſo much improved by it as by lime. Its effects laſt two years, and are greateſt upon ſtrong and rich land. One of the beſt ways of uſing it is to ſcatter it upon wheat-ſtubble, to promote the growth of clover ſown in the ſpring, and harrowed in among the wheat. The gypſum muſt be thrown on the ſtubbles in autumn, or the following ſpring. If done ſooner, it would fill the wheat with weeds. The quantity need not exceed that of the grain ſown. It is uſed in Switzerland, even at a very great expence, both in a raw and calcined ſtate; chiefly on the graſs lands, as a top dreſſing. I do not find, however, that the trials made of it in this country have been ſucceſsful. Yet it ſeems unwarrantable to doubt the numerous and circumſtantial accounts given by the Economical Society of Berne, compoſed of perhaps the moſt intelligent practical farmers in Europe.

2.—*Fluor, or Fluat of Lime.*

Since the compounded nature of gypſum was diſcovered by Mr. Margraaf, another kind of ſtony matter, which was formerly known by the name of *fluor*, and *fluor mineralis*, and conſidered as a particular ſpecies of earth, has been found to be another compound of the calcareous earth with an acid. We owe this diſcovery to Mr. Scheele of Sweden, whom I have often had occaſion to mention with praiſe; and in conſequence of the light he has thrown upon the compound I ſpeak of, it deſerves now to be conſidered as one of the moſt remarkable objects of philoſophical chemiſtry.

The ſtone or ſtony ſubſtance I ſpeak of, is called by the Germans

flus, or *flus ſpat;* in the books of natural hiſtory, *fluor* and *fluor ſpathoſus*. It had theſe names from its effect in promoting the melting of ores and minerals in metallurgical operations.

Its appearance and more obvious qualities are theſe: It is a ſtony ſubſtance, which, ſo far as I know, never compoſes ſtrata, but is always found either in veins, or in ſmall maſſes. It has a cloſe glaſſy texture, and receives a fine poliſh, and generally is tranſparent, though often tinged of a green colour, or purple, or yellow, or deep blue. There is much of it in Derbyſhire; and on account of theſe colours, it is called in England, *blue John;* and formerly in apothecaries ſhops, *falſe emerald*, *falſe amethyſt*, &c.

It is often found cryſtallized in the cavities of veins; and the moſt regular form of its cryſtals is cubical.

In point of hardneſs, it holds a middle place between the calcareous ſtones and the ſtones of the hard claſs; being too hard to be eaſily affected by the edge of a knife, but not too hard to be cut or ſcraped with hard ſteel, and capable of being wrought by the turner with proper inſtruments, and formed into very thin and delicate veſſels.

It has a quality which is found alſo ſometimes in the cryſtals of calcareous ſpar; but this ſtone has it more generally: I mean a power to emit light, or a ſubtile luminous volatile matter, when the ſtone is heated. After it is once red hot, it ſhines no more. I ſaid "emits a luminous matter,"—for the phoſphoreſcence of fluor is accompanied by a pretty ſtrong unpleaſant ſmell; and there is a kind of it mentioned by Mr. Wedgewood junior, in his obſervations on phoſphoreſcent bodies, which is fœtid when rubbed, and this kind is much more luminous than the others. The light is firſt green, then verges to a purple or lilac. (*Phil. Tranſ.* 1791.)

When we apply a violent heat to this ſubſtance, it melts moſt perfectly; and is very powerful in promoting the fuſion of other earthy ſubſtances,—eſpecially if calcareous ſpar and it be mixed together; then flowing almoſt as thin as water. Whence it is much valued for the

ſmelting of ores. If we melt any conſiderable quantity of it in a crucible by itſelf, or without adding any thing to it, ſuch is its power to diſſolve other earthy ſubſtances in the fire, or to promote their fuſion, that it will melt the bottom of the crucible and run out.

The moſt ſurpriſing part of this ſubſtance is the acid which it contains, and which can be expelled from it by the ſulphuric acid. To effect this ſeparation of the acid, the fluor muſt be reduced to a very fine powder, and an equal, double, or even triple, weight of the ſtrongeſt ſulphuric acid muſt be poured on it in the retort. As ſoon as the materials are mixed, they begin to act ſlowly on each other. We muſt apply heat to quicken their action, and join a receiver, previouſly warmed (to expel ſome of its air) having water in it to promote the condenſation of the acid. While the water attracts and condenſes the vapours, a white and very tender ſpongy earth is uſually depoſited on its ſurface, and hinders the further condenſation. We muſt agitate the veſſels to break this cruſt, and then the condenſation is renewed. And thus, by frequent agitations, we condenſe the whole acid. Such a quantity of earth is precipitated as to make the water quite thick. The glaſſes are found much corroded by this proceſs. For a more particular account of it I refer you to Scheele's Eſſays,—eſſay 1.

Mr. Scheele called this acid the *acid of ſpar*, or *acid of fluor*. It is now called FLUORIC ACID, and its compounds are called FLUATS. It is very volatile, like the muriatic acid, and will not condenſe without water. But it differs from the muriatic acid by many properties; as, 1*ſt*, By forming with calcareous earth a compound perfectly inſoluble in water. 2*dly*, It has the power to diſſolve, and even volatilize, the ſilicious earth, which is perfectly inſoluble by other acids. And 3*dly*, It has a greater attraction for lime than for alkalis; and it forms peculiar compounds with the alkalis, alkaline earths, and metallic ſubſtances.

Mr. Scheele learned by a number of experiments, that this fine earth, which is mixed with the acid in the receiver, has all the qualities

which belong to the ſilicious when in fine powder. And a further inveſtigation by Mr. Scheele, and by other chemiſts, has proved that this ſilicious earth is generally a part of the materials of the glaſs veſſels diſſolved and volatilized by the acid, but depoſited again in part, when the acid vapours unite with water. This was proved by diſtilling the ſpar in a retort of lead, and condenſing the vapours in a receiver of lead, or of glaſs defended with wax. Thus we get a pure acid, not tainted with ſilicious earth. There are, however, ſome varieties of this ſpar unfit for this experiment, on account of their containing ſome ſilicious earth in their compoſition, which is diſſolved and volatilized by the acid during the diſtillation. I could find no difference between this curious compound, and the pureſt ſilicious earth that I could obtain from liquor ſilicum by precipitating it by the ſulphuric acid. I ſubjected theſe compounds to a great variety of trials. But whether the acid be tainted with ſilicious earth in this manner, or in conſequence of its being diſtilled in glaſs veſſels, there is a method by which the ſilicious earth can be ſeparated and the acid obtained pure, viz. by ſaturating the acid with volatile alkali, which precipitates the whole ſilicious earth from it, and forms with it an ammoniacal ſalt, purely ſaline. If a quantity of this ammoniacal ſalt be prepared, and then decompounded with ſulphuric acid in leaden veſſels, a pure ſpatoſe acid is thus obtained; ſometimes, indeed, not quite pure, but tainted with a little muriatic acid. But Mr. Scheele has taught a method, by means of ſilver precipitated from nitrous acid, for ſeparating this alſo. The fixed alkali cannot be employed to precipitate the ſilicious earth and to form a pure ſaline compound: It has an attraction itſelf for the ſilicious earth, and forms a triple compound, from which it is impoſſible to obtain by cryſtallization a pure neutral ſalt.

Mr. Scheele diſcovered many other qualities of the acid of fluor which it ſhews in mixture with metals, &c. for which I refer you to his eſſay.

Some of the French chemiſts committed great miſtakes and errors in their firſt experiments and reaſonings concerning fluor and its acid. You will ſee Mr. Scheele's remarks on them in his eſſays. And Mr. Scheele himſelf was at firſt in a miſtake with reſpect to the origin of this ſilicious earth, which this acid depoſits in uniting with water.

Fluor is diſſolved by nitric acid or muriatic acid. Sal tartari precipitates calcareous earth from this ſolution. But cauſtic alkalis, or aërated volatile alkali, precipitate fluor in fine powder. Sulphuric acid precipitates gypſum. A gypſum is alſo formed by adding to the ſolution Epſom ſalt, or vitriolated tartar, or vitriolic ammoniac, which alſo acts by ſublimation, in decompounding fluor by double elective attraction.

Phoſphoric acid decompounds fluor by diſtillation, and the reſiduum is a ſubſtance perfectly the ſame with bone aſhes.

Diſtilled vinegar and acid of tartar have no effect on fluor.

Cauſtic fixed alkali melted with fluor, does not decompound it, but may be afterwards ſeparated by water, and it leaves the fluor unchanged. Mild fixed alkali, four parts, melted with powdered fluor, one part, decompounds it. The fixed alkali joins with the fluoric acid, and forms a ſalt not deliqueſcent. The reſt is mild calcareous earth. A ſolution of mild fixed alkali decompounds by digeſtion fluor made of lime-water, and fluoric acid.

The acid of fluor may be obtained without employing any foſſil acids. Melt the fluor with mild fixed alkali, and extract the compound ſalts from the mixed matter by means of water. To the ſolution add acetated lead. We obtain a precipitate, which, when expoſed to a ſtrong heat in a retort with charcoal duſt, gives reduced lead and the ſpatoſe acid.

Fluor mineralis, if pure from quartz, can be diſſolved completely by aqua regia. The fluor muſt be in fine powder, and muſt be digeſted with a ſufficient quantity of the aqua regia. Bergmann *(on Elective*

Attractions, p. 123.) propoſes this as a trial, to learn whether the fluor had contained any quartz.

The moſt remarkable property of the acid of fluor is its action on ſilicious earth, which is ſuſceptible of no union with any other acid, ſo far as has yet been diſcovered. Mr. Bergmann has given a curious example of this. He put into a phial ſome finely powdered quartz, and having filled it with diluted acid of fluor, he cloſed it up. After two years, he found intermixed with the flinty powder thirteen cryſtals as big as ſmall peaſe. They were of various forms; ſome were hexahedral pyramids; others were ſimilar pyramids on the end of hexahedral columns; moſt of them, however, were cubes, having the angles cut off. They had all the chemical qualities, and wanted little of the hardneſs of perfect quartz. Hence he was induced to believe that this acid had great influence in forming the hard-figured foſſils.

This action on ſilicious earth has been applied to a very curious purpoſe, namely, engraving, or more properly ſpeaking, etching on glaſs. A German nobleman, and Mr. de Puymarin of Thouloufe, without knowing of each others labours, reflecting on Scheele's experiments, applied the acid to this uſe. The plate was covered with engravers varniſh, and traced with points in the uſual manner. A border of wax being alſo made as uſual round the plate, it muſt be covered with a mixture of equal parts of pounded fluor and vitriolic acid, and left there two or three days *.

* This action on glaſs has been known long before. In 1670, an artiſt at Nurenburgh, named Schankhard, practiſed it. Alſo in 1725, one Pauli in Dreſden, employed it for etching on glaſs. (See *Beckman Hiſtory of Inventions*, *t.* iii. *p.* 547. *Alſo Breſlaw Collection*, xxxi. 1725. *p.* 107.) Little ſeems to have been done with it, and it was forgotten till Scheele's experiments revived the art on principle.

The etching done in this way is far from being neat. As ſoon as the acid gets at the glaſs, it eats away ſideways below the varniſh. Alſo the lines are extremely ſhallow, and when viewed through a microſcope, ſhew us that the acid acts unequally on the different ingredients of the glaſs. The glaſs ſeems to exfoliate.

EDITOR.

3.—*Phoſphat of Lime.*

The next ſingular and remarkable compound of the calcareous earth with an acid, is the PHOSPHAT OF LIME. This was firſt diſcovered and analyſed by Mr. Scheele, in company with another Swediſh chemiſt, Mr. Gahn.

This compound conſiſts of lime, or calcareous earth, combined with a particular acid which was diſcovered firſt, or firſt deſcribed with preciſion, by that excellent chemiſt Margraaf of Berlin. It is now called the phoſphoric acid. He found it in the ſalt which firſt cryſtallizes from urine, when it is evaporated to about $\frac{1}{3}\frac{1}{0}$. This is called *ſal microcoſmi, ſal microcoſmicum.* He alſo diſcovered that the phoſphorus of urine, of which we ſhall ſpeak when we deſcribe the inflammable ſubſtances, is converted into this acid by inflammation. It was therefore called PHOSPHORIC ACID.

The phoſphoric acid reſembles the boracic, by enduring, in its pure ſtate, very ſtrong red heats, without being changed into vapour. It only melts very eaſily into a tranſparent ſubſtance like glaſs. This glaſſy-like matter diſſolves, however, eaſily in water, but cannot be cryſtallized. It forms with the water a liquid acid, from which the water can be evaporated again; but near the end of the evaporation, the remainder of the water is ſtrongly retained; and when forced off by heat, carries away a part of the acid, as you know happens with the boracic.

Mr. Margraaf diſcovered a great many properties of this phoſphoric acid, which are detailed in the Berlin memoirs. But he did not know that it exiſted in any other natural productions excepting urine, and the ſeeds of ſome plants in which he diſcovered it.

More lately, however, ſince the ſtudy of the productions of nature has ſo much engaged the attention of philoſophers, the phoſphoric acid has been found in other ſtates or conditions. The firſt example of this was diſcovered by Mr. Scheele, and Mr. Gahn of Sweden,

who were making a ſet of experiments in company. They made ſome on the earthy part of bones and horns, commonly called bone-aſhes, that is, the white matter which remains from bones and horns, when all the inflammable matter has been completely burnt out of them. This white matter was formerly kept in our apothecaries ſhops, under the name of *cornu cervi calcinatum*, and it was ſuppoſed to be an alkaline earth. I gave a few experiments on it in the eſſay of magneſia, which ſhewed that it had very little of an alkaline quality. But the Swediſh chemiſts, having examined it with different views, and in a quite different way, found it to be compounded of calcareous earth and phoſphoric acid. Their firſt proceſs for decompounding it has been reduced to greater ſimplicity by other chemiſts. This ſimpler proceſs is given very diſtinctly in the laſt edition of the Edinburgh Pharmacopœia, as a ſtep in the proceſs for preparing the *ſoda phoſphorata*, which is a phoſphat of ſoda, recommended lately by Dr. Pearſon at London, as a pleaſant and effectual laxative and purgative.

Since Scheele and Gahn publiſhed their proceſs for analyſing bone aſhes, a ſimilar compound, or phoſphat of lime, has been found in vaſt abundance among the foſſil productions of nature. The firſt example of this was communicated by a letter from Mr. Prouſt, an able chemiſt, in the ſervice of the King of Spain, to Mr. Darcet of the late French Academy of Sciences, and publiſhed in the Journal de Phyſique June 1788, informing him that in Eſtremadura it conſtituted extenſive rocky ſtrata. Mr. Prouſt found it in a ſtone ſo abundant in the province of Eſtremadura, that it is quarried and employed in building. In appearance, it reſembles a ſtone compoſed of felt ſpar; but it conſiſts of the calcareous earth ſaturated with phoſphoric acid, or at leaſt containing it in the ſame proportion with the earth of bones, that is, nearly one-fifth. It is highly phoſphoreſcent when heated. It is alſo found in Saxony and in Bohemia. Mr. Werner diſcovered it ſimilar to the Spaniſh in Saxony. At Schlack-

enwaldt, in Bohemia, it is found cryſtallized; generally in ſix-ſided priſms, and alſo in the forms of tables and plates. It is ſeldom ſolitary, but generally mixed with fluor, ſpar, litho-marga, ſteatites, and ſeveral of the metals. It is rarely accompanied with quartz, as it is in Spain. The Germans ſay that it contains 45 parts of phoſphoric acid per cent, and they call the compound *apatit*. I ſuſpect that there is ſomething like it in the north of Ireland, near the Giant's Cauſeway. And, perhaps the fœtid marbles, and *lapis ſuillus*, are of this nature.

The phoſphat of lime is uſed in making veſſels for the refinement of ſilver and gold, to be deſcribed hereafter. From it too the phoſphoric acid is now obtained. And lately, it has been recommended by a French practitioner as a remedy for the rickets. We ſhall have a better opportunity for treating of its decompoſition, when we conſider it as the matrix of phoſphorus. This intereſting proceſs has occaſioned this compound to be tortured in every way that chemiſtry can diſcover.

4.—*Borat of Lime.*

There now remains to be mentioned but one more compound, formed by nature, of the calcareous earth with an acid: And it has been but lately diſcovered, (in 1791.) It is a compound of this earth, and partly too of magneſia, with the boracic acid. It is found cryſtallized. From its hardneſs, it was miſtaken at firſt for ſilicious matter. The above cryſtals are found near Lunenburgh, in the Duchy of Brunſwick, in a vein of a mountain which abounds with gypſum. It is called cubical quartz. For an account of it ſee the *Annales de Chymie*, *tome* ii. *p.* 101, by Mr. Weſtrumb, and *p.* 132, by Mr. Heyer. It contains about two-thirds of its weight of ſedative ſalt, about one-eighth of magneſia, one-tenth of lime, and ſome other earths.

SPECIES III.—BARYTES.

Thus far we have been employed in conſidering the common calcareous earth, or lime, and ſome remarkable compounds which it forms in nature with different acids.

I am next to make known to you two other kinds of earthy or ſtony bodies, which bear a great reſemblance to the calcareous by ſome of their properties, though they are quite different from it by others; and the differences are of great importance.

One of the earths I now mean had firſt the name of TERRA PONDEROSA, on account of its being remarkably heavy. Now that name is changed to BARYTES, derived from the Greek, and alluding to the ſame property.

When reduced to its pureſt ſtate, it has the acrimony and activity of lime, which it ſhews by its acrid taſte and corroſive quality, like thoſe of common lime. It likewiſe diſſolves in water, ſo as to form a lime-water, which, however, contains leſs of the earth diſſolved in it than common lime-water does, viz. only $\frac{1}{900}$th; that is, very little more than half a grain to the ounce.

In this pure and active ſtate, it alſo decompounds the ammoniacal ſalts readily, and diſſolves ſulphur, by boiling in water, as common lime does.

It has a ſtrong attraction for fixed air, or carbonic acid; and, when joined with it by art, forms a ſpecies of chalk, quite inſipid, and which effervesces with acids. The attraction of this earth for fixed air is ſo ſtrong, when it is pure, that it readily takes it from the alkaline ſalts, and renders them cauſtic; and the air is with difficulty ſeparated from it by fire. It contains, however, much leſs fixed air than crude calcareous earth, and vaſtly more water, almoſt one-third of its weight.

When combined with fixed air, or in the ſtate of a chalk, it can be

diſſolved in ſmall quantity by aërated water. When calcined, it diſſolves ſulphur.

In all theſe particulars, therefore, it agrees with the common calcareous earth.—It differs from the ſame earth,

1. By its weight, or the weight of the compounds which it forms with acids. They are all much heavier than the correſponding compounds formed by the calcareous earth.

2. It differs from the calcareous earth by having a ſtronger attraction for acids in general, and eſpecially for the vitriolic acid. It has the power to ſeparate moſt of the acids, but eſpecially the vitriolic acid, from the fixed alkalis, as well as from lime. This conſtitutes a very remarkable, and often a puzzling diſtinction.

3. The compound which it forms with the vitriolic acid is much more denſe and heavy than common gypſum, and it is *perfectly* inſoluble in water.

4. With nitric or with muriatic acid it forms ſaline compounds, ſoluble in water, but not deliqueſcent like the compounds of the ſame acid with lime. On the contrary, the nitrat and muriat of barytes are eaſily cryſtallizable. The cryſtals of the nitrat are of various flattiſh forms, as if they were ſlices of a very low pyramid. The cryſtals of the muriat are alſo ſlices of a very low pyramid; but their baſe is always an oblong rectangle, but generally having the four angles truncated, ſo as to make it an octagon, having very unequal ſides.

With the acetous acid barytes forms a deliqueſcent ſaline compound, not cryſtallizable; the reverſe in this reſpect of the compound formed by lime.

After the vitriolic acid, the acid of ſugar has the ſtrongeſt attraction for barytes, and, next to it, the acid of ſorrel. Theſe are very remarkable diſtinctions.

The ſtate in which barytes is moſt commonly or abundantly found in nature, is combined with the ſulphuric acid, or under the form of a ſulphat of barytes. In this ſtate it occurs moſt frequently in the veins

of the mountains in whicch ores of metals are found; for which reaſon it is called by ſome authors MARMOR METALLICUM. But in ſome rare veins it has alſo been found combined with the carbonic acid, or in the ſtate of carbonat of barytes. It is found in this ſtate in the mine called Angleſark, near Chorly, in Lancaſhire. *(Vide Mancheſter Memoirs.)*

This earth has lately become an intereſting object, ſince it has been found to have very uncommon and valuable powers in medicine. This appears from Dr. Crawford's trials of it, in a number of caſes publiſhed in the ſecond volume of *Medical Communications* of a Society at London. He gave it in caſes of ſcrophula, or bad ſores, and obſtructed glands. Its ſenſible effects were gently to increaſe appetite, and the diſcharge by urine and perſpiration. Theſe effects were in ſome caſes impeded at firſt by plethora, or an inflammatory diatheſis, which was removed by a vegetable diet. He has publiſhed all the caſes in which he has tried it, which is a very candid way of communicating the knowledge of any new medicine. And it evidently has eminent healing powers. Much caution, however, is required in the uſe of it, as too large doſes of it might prove a poiſon. He, therefore, warns practitioners to diminiſh the doſe, when it produces nauſea or giddineſs. Mr. Watt poiſoned dogs with half a drachm of it. Profeſſor Blummenbach, of Gottingen, found that the warm blooded animals only are with certainty poiſoned by it; while both the warm and cold blooded animals may take with ſafety the ſimilar compounds of an earth which has been confounded with it, and will be deſcribed in the next place.

SPECIES IV.—STRONTITES.

The other alkaline earth, which I ſaid reſembles the calcareous, by ſeveral properties, has been known for ſome time in this country as occurring in ſome of our mines, and was ſuppoſed to be the barytes,

or a mixture of it with calcareous earth; until lately that Dr. Hope of Glaſgow employed himſelf in examining it, by a number of experiments, which he communicated to our Royal Society here. His experiments were very judiciouſly planned, and the concluſions he drew from them are perfectly well ſupported. I ſhall now give a general abſtract of them.

He finds reaſon to conclude that it is a peculiar ſpecies of alkaline earth, different from any deſcribed before. The mine in which it is found intermixed with other ſpars is in the weſt of Scotland, near a village called Strontian: He therefore gives it the name of STRONTITES.

1. The carbonat of ſtrontites of Dr. Hope is of a ſpecific gravity from 3.650 to 3.726. The natural carbonat of barytes is 4.338. The carbonat of lime is about 2.700.

2. Its external characters are,—conſiderable hardneſs, fibrous or cryſtallized texture, muddy tranſparency, and colour inclining to yellow or green.

3. It is inſipid, but has a little ſolubility in water. Four ounces of diſtilled water being boiled with 10 grains of it in fine powder, diſſolved $2\frac{1}{2}$, $=\frac{1}{768}$.

4. The gas extricated during its effervescence with acids is carbonic acid gas; and it loſes 30.2 per 100 during effervescence.

5. The greateſt heat of a common open fire is not ſufficient to expel its air, but only makes it decrepitate a little, and become opaque by the loſs of ſome water.

A violent heat in a ſmith's forge, of 45 minutes, applied to a ſmall maſs of ſtrontites incloſed in a Sturbridge clay crucible, and which ſoftened the crucible, melted the outſide of the maſs into a green glaſs; while, within this vitrified cruſt, the reſt was white, opaque, and cauſtic. When it is thus rendered cauſtic, it loſes 38.79 per 100 of its weight. With water it now unites in the ſame manner as quicklime, but more violently, and is ſlaked by the air in the ſame manner. The vitrified part being dropped into muriatic acid, is ſlowly

acted on. At length a jelly is formed, which becomes perfectly fluid by the addition of water; a minute portion of powdery matter, which probably came from the crucible, remained undiſſolved.

Dr. Hope was not able to vitrify ſtrontites with the flame of the blow-pipe. This makes it emit a brilliant light. *(Fourcroi.)*

The conſtituent parts of natural carbonat of ſtrontites, are by the above experiments, in 100 parts,

Earthy baſis, - -	61.21
Carbonic acid, - -	30.20
Water, - -	8.59
	100.00

6. Hot water diſſolves a much larger quantity of pure or cauſtic ſtrontites than cold water, and in cooling depoſites the ſuperfluous quantity in cryſtals. It is very remarkable by the great quantity of heat which is extricated from it in ſlaking. A few ſmall bits thrown into a flaſk of hot water, make it boil violently, and the ebullition may be kept up for a great length of time by freſh additions. Nine ounces and a half of water yielded by refrigeration rather more than an ounce of tranſparent cryſtals. A hundred grains of theſe cryſtals contain 68 of water. one part of which is eaſily expelled from them by heat, at firſt without fuſion, but at laſt a part of the water adhering more ſtrongly, makes them undergo a watery fuſion, which ceaſes when the water is totally evaporated. Theſe cryſtals muſt be kept in phials very cloſely ſtopped, otherwiſe they attract carbonic acid, and fall down in powder. The great quantity of water rendered ſolid in theſe cryſtals, and ſo ſtrongly united, accounts for the great heat produced by mixing calcined ſtrontites with water.

One ounce of water at 60° Fahrenheit, diſſolves ſlowly 8.5 grains of theſe cryſtals. One ounce of water kept boiling diſſolved no leſs than 218 grains. Theſe ſolutions have all the alkaline qualities of lime-water.

(N. B. Dr. Hope diſcovered that barytes can alſo be cryſtallized in the ſame manner.)

7. Sulphuric acid forms with ſtrontites a compound more difficultly ſoluble than gypſum. Four ounces of diſtilled water, boiling, diſſolved only one-half grain. The ſolution was rendered turbid by carbonat of potaſh, by barytic water, and by muriat of barytes.

Sulphuric acid diſſolves the ſulphat, and dilution makes it ſeparate again.

8. Nitric acid diluted diſſolves it totally, but does not act on it when not diluted. It rather precipitates a nitrat previouſly formed. The ſolution eaſily yields cryſtals, which are octohedral, or formed of two four-ſided pyramids joined by their baſis. One ounce of water, at 60°, diſſolves one ounce of theſe cryſtals; and at 212°, one ounce ſeven drachms fourteen grains. In dry air, a part of their water is evaporated from them. In very moiſt air they deliqueſce. They deflagrate with combuſtibles, and give a bright red flame or light. Or if they be expoſed to heat alone, they loſe the acid, and the pure or cauſtic earth remains.

9. Muriatic acid muſt alſo be diluted to diſſolve ſtrontites. And the ſolution gives long ſlender ſix-ſided cryſtals, often diſpoſed in a radiated form. (N. B. By this mode of cryſtallizing, this earth is diſtinguiſhable from others. By putting a little of the muriat on a plate of glaſs, it will evaporate and cryſtallize. The muriat of barytes cryſtallizes into plates which are much leſs ſoluble in water.) Theſe cryſtals are not pulveriſed by the air, but in extremely damp air ſhew a tendency to deliqueſce. One ounce of diſtilled water, at 60°, diſſolves one ounce four drachms one ſcruple of them. One ounce of water kept boiling, diſſolves four ounces, or more. They contain 42 per cent. of water, and undergo the watery fuſion. But the acid is not eaſily ſeparated by heat. The muriatic acid may, however, be expelled from the ſtrontites, by the heat of a blow-pipe applied to it in a platina ſpoon.

10. Acetous acid diſſolves ſtrontites ſlowly. The ſolution tinges vegetable colours green; and by ſpontaneous evaporation, gives minute undiſcernable cryſtals. One ounce of water diſſolves, in a boiling heat, 196 grains of them, which remain diſſolved when the water cools.

11. The oxalic, tartarous, and fluoric acids, form very inſoluble compounds.

12. Phoſphoric acid, applied in large quantity, diſſolves it ſlowly; but if we attempt ſaturation, the whole compound precipitates. Four ounces of boiling water diſſolved only one grain from 10 of this precipitate.

13. With ſuccinic acid it forms cryſtals which are durable in the air.

14. Acid of arſenic forms a ſolution which cannot be evaporated by heat, without undergoing a change in which the earth is more cloſely combined with the acid, and alſo with a ſmaller quantity of it than before; and this new ſtate of combination renders the compound inſoluble. One ounce of boiling water was able to diſſolve little more than one grain.

15. With boracic acid, it is ſenſibly alkaline, and water diſſolves $\frac{1}{130}$.

16. With carbonic acid it preſents the ſame phenomena as thoſe which are exhibited by lime.

17. Strontites, and all its compounds, give a red colour to flame. The muriat does it moſt, and is beſt uſed for this purpoſe by putting a cryſtal of it on the wick of a candle. Muriat of lime alſo produces this effect in ſome degree; but muriat of barytes gives a greeniſh colour to flame. A certain portion of humidity is neceſſary to enable theſe compounds of ſtrontites to tinge the flame. Without it they have no effect.

18. Aërated alkalis precipitate ſtrontites from its ſolutions; at firſt in form of a gelatinous matter, but by adding more alkali, and agitation, an opaque white curdled precipitate is formed, which Dr. Hope calls

artificial carbonat. It loſes its air more eaſily in the fire, and diſſolves more quickly in acids than natural carbonat, but is in every other reſpect the ſame.

19. The pruſſiat of potaſh or of lime do not in the leaſt precipitate ſtrontites from its ſolutions in acids; in which property it differs remarkably from barytes.

20. With ſulphur it forms a hepar, either in the dry or humid way, in the ſame manner as lime.

21. Cryſtals of cauſtic ſtrontites were diſſolved, but very ſparingly, by alcohol, which afterwards burned with a reddiſh flame.

The following is the order of attractions of the acids for ſtrontites: Sulphuric acid, oxalic, tartarous, fluoric, nitric, muriatic, ſuccinic, phoſphoric, acetous, arſenical, boracic, carbonic.

Strontites compared with other alkaline ſubſtances in its force of attraction for the different acids.

Sulphuric Acid.	Oxalic Acid.	Tartarous Acid.	Fluoric Acid.	Nitric Acid.
Barytes,	Barytes, }	Lime,	Lime,	Barytes,
Strontites,	Lime, }	Barytes,	Barytes,	Potaſh,
Potaſh,	Strontites,	Strontites,	Strontites,	Soda,
Soda,	Potaſh,	Potaſh,	Potaſh,	Strontites,
Lime.	Soda.	Soda.	Soda.	Lime.

Muriatic Acid.	Arſenical Acid.	Boracic Acid.	Phoſphoric Acid.	Carbonic Acid.
Barytes,	Lime,	Lime,	Lime,	Lime, }
Potaſh,	Barytes,	Barytes,	Barytes,	Barytes, }
Soda,	Potaſh,	Strontites,	Strontites,	Strontites, }
Strontites,	Soda,	Potaſh,	Potaſh,	Potaſh,
Lime	Strontites.	Soda.	Soda.	Soda.

GENUS II.

PLASTIC EARTHS.

WE ſhall now proceed to ſtudy the ſecond order of the earths,—the PLASTIC, which are commonly called in our language CLAYS, or CLAYEY EARTHS.

The natural earths which are aſſembled under this diviſion, all contain more or leſs of a particular kind of earth in their compoſition, which gives them their plaſtic qualities, or gives them, in different degrees, the qualities which belong eſpecially to itſelf.

The earth I now mean is at preſent conſidered by the chemiſts as another of the pure elementary earths, and is called the argillaceous. It is diſtinguiſhed from the earths hitherto deſcribed by theſe properties:

1*mo*, It does not effervеſce with acids when they are ſimply mixed with it.

2*do*, It is compoſed of exceedingly fine impalpable particles: It therefore feels fat or ſmooth between the fingers, like marrow; and is not in the leaſt gritty between the teeth.

3*tio*, When a dry maſs of it is applied to the tongue, it imbibes the ſuperficial humidity of that organ ſo ſtrongly that it adheres to it; and it gives a peculiar odour on all theſe occaſions when humidity is applied to it.

4*to*, If it be mixed and well kneaded, and worked with a proper quantity of water, it forms a ſoft and plaſtic maſs, not eaſily diffuſible or dilutible in more water, and which, if dried well, and afterwards burned with a ſtrong heat, becomes very compact and hard, and impenetrable by water.

5*to*, It has ſome notable qualities which it ſhews in mixture with acids; the moſt remarkable of which qualities ſhall be mentioned preſently.

The plaſtic earths, therefore, all contain more or leſs of this ſimple earth; and they conſtitute every where numerous ſtrata. They alſo make a part of every ſtrong and rich ſoil.

That property of plaſtic earth, by which they become ſo tough a paſte, and ſo difficultly diffuſible or penetrable by water, when wrought and compreſſed with a proper quantity of that fluid, occaſions their being employed for confining water in canals, and ponds, and reſervoirs, and other works in which large quantities of water are to be confined, or preſerved from being waſted by ſoaking through the ſoil. It alſo explains the bad effects of what is called *poaching* clayey grounds; that is, allowing cattle to tread on them much when they are wet or ſoft, as they are thus reduced to that plaſtic ſtate in which they do not tranſmit water eaſily, but occaſion it to ſtagnate on their ſurface, and to rot or ſicken the plants; and at the ſame time they are ſo denſe and viſcid, that the roots of plants cannot penetrate them without the greateſt difficulty. The remedy for this is, to plough them when they are moderately dry, and when dry weather or froſt is expected. If the clods once become dry, the firſt rain will make them moulder down, and alternations of dry weather and ſhowers will completely divide them.

Mr. Bergmann ſays that a fine clay does very well for waſhing and cleanſing linens. Though it does not chemically combine with greaſy filth, it adheres to it, and carries much off with it by rub-

bing. *Smectis*, or *fuller's earth*, is a marly clay, and is much employed in this way.

There is great variety of the earths which come under this diviſion, and under the common denomination of clay. They are various by their colour, by the fineneſs and ſmoothneſs of their particles, by their degree of coheſion when we attempt to diffuſe them in water, and the degree of toughneſs, or plaſtic quality, which they aſſume when wrought or kneaded with a proper quantity of that fluid; and alſo by their qualities with reſpect to heat, or the changes they undergo from the different degrees of its action on them. But all this variety is produced by the various admixture of ſiliceous earth, or magneſia, or calcareous earth, or iron, or inflammable and other matters, in various proportion with the argillaceous earth. It is ſo liable to admixtures of this kind, that a pure argillaceous earth is one of the rareſt productions of nature; and in the very few examples that have occurred, it was in ſmall quantity.

The clays which contain it in the greateſt quantity, or in a ſtate leſs impure than ordinary, are either naturally white, or if they have a dark or dull colour, it proceeds from a ſmall quantity of inflammable matter; and they become white when burnt in an open fire. Thoſe that become red in the fire contain iron.

Clay, by being kept very long in a wet ſtate, becomes evidently ſour to the taſte and ſmell. I was aſſured of this fact by Mr. Wedgewood, who is perhaps the moſt perfectly acquainted with all the qualities of the plaſtic earths of any perſon in Europe, and the moſt intereſted to know them in their ſtate of greateſt purity. The fact is curious, and perhaps important to the chemical philoſopher. Perhaps it receives ſome explanation from another fact which he alſo told me, viz. That by long expoſure to the air, the ſurface appears powdery; and when this duſt is carefully ſwept together, it is found tainted with a calx of iron. It is not unlikely that this ariſes from a minute portion of pyrites, which is known to de-

compound by humidity, and to yield its acid. May not this alſo account for the hardening of clays by the fire, even in their pureſt ſtate?

The moſt uſeful qualities of clays in the arts are,—their diſpoſition to conſtitute, with a proper quantity of water, that ductile plaſtic maſs, which is eaſily formed on the potter's wheel, or otherwiſe, and which can be baked afterwards by fire to a ſtony hardneſs. In conſequence of which, they are employed for the manufacture of numerous veſſels, tiles, bricks, and many other uſeful productions of art. The beſt kinds of it acquire different degrees of compactneſs and hardneſs in the fire, according to their dryneſs in the firſt kneading, and the violence of the heat.

When clay has been made very ſoft, by kneading it with much water, in order to make it work eaſily on the potter's wheel, it muſt be very porous when burnt to a tile: For whatever quantity of water be employed, the piece does not contract much by drying; and by no means in proportion to the water in it. Such ware, therefore, muſt be very open and ſpongy, and may be uſed for filtres *.

In a moderate red heat they become hard, but porous, and are formed into tobacco pipes, &c. In a much ſtronger one they are rendered compact and hard like flint. But pure clays never melt in ordinary furnaces or fires. The more coarſe and impure clays have theſe qualities in inferior degrees. They do not grow ſo hard in moderate heat; and many of them cannot withſtand a ſtrong fire without melting, on account of the mixture of different earthy ſubſtances

* Accordingly, veſſels of this porous ware are uſed in the hot climates for cooling liquors; which ſervice they perform by the copious evaporation from the ſurface. Veſſels are alſo made in this country as porous as poſſible, and have their external ſurface turned into deep notches, or furrows, on the potter's wheel. They are filled with water; and ſmall ſeeds, ſuch as thoſe of creſſes and muſtard, are ſprinkled into thoſe furrows, where they receive enough of moiſture to make them grow, and cover the outſide with foliage. A ſallad is thus eaſily raiſed at ſea, and in winter in a warm room.

EDITOR.

and other matters which they contain, and which give them this diſpoſition.

Experiments made with clays, in the way of mixture with other ſubſtances, have ſhewn that the argillaceous earth, although it does not effervеſce with acids, can be combined with them; and that, when combined with the ſulphuric acid, it conſtitutes ALUM.

This, however, is a late diſcovery, for although alum has long been in uſe, and well known to contain the ſulphuric acid combined with an earth, the nature of this earth was not diſtinctly underſtood, until two of the academicians of Berlin, Pott and Margraaf, publiſhed their experiments on this ſubject, in which they made perfect alum by diſſolving the argillaceous earth of clays in the ſulphuric acid. Mr. Pott made the firſt ſtep in this diſcovery, and Mr. Margraaf afterwards brought it to perfection.

It was aſcertained by Mr. Margraaf's experiments that the argillaceous earth can be combined with the vitriolic acid in two different proportions, or ſo as to form two compounds conſiderably different. One of them contains a large proportion of the acid, and is very ſoluble in water, and deliqueſcent, and cannot be cryſtallized: This is called *alum liquor*. The other, viz. *alum*, contains a ſmall proportion of acid to the earth, and is but moderately ſoluble in water, and eaſily cryſtallizes, and is not at all deliqueſcent, but rather calcines ſpontaneouſly.

The firſt of theſe two compounds is almoſt always formed when we attempt to make alum by combining its two ingredients, which may be done by boiling the beſt kinds of clay in ſtrong ſulphuric acid until the mixture is dry, and then adding water to diſſolve the alum or aluminous compound which has been formed. We thus get an alum liquor, or acidulous liquid alum, from which it is neceſſary to abſtract a part of the acid, by adding a ſmall quantity of an alkaline ſalt, or by a proper degree of heat, before we can have alum that can be cryſtallized.

Mr. Beaumé of Paris has made an addition to theſe diſcoveries of Margraaf. He diſcovered that a third compound can be formed of the ſulphuric acid and aluminous earth ;—a compound in which there is ſtill leſs of the acid than in perfect alum ; and which is therefore not ſoluble in water. This compound is formed by boiling a ſolution of alum in water with ſome of the pure argillaceous earth ; the conſequence of which is, to change the whole of the alum into this third compound, which ſubſides to the bottom, and forms a ſediment which cannot be diſſolved.

All theſe particulars have been diſcovered by the experiments made to combine the ſulphuric acid in different ways with the argillaceous earth.

It is not, however, in this way that alum is manufactured for the purpoſes of different arts : It is obtained from materials which afford it much cheaper, by a proceſs which was long practiſed before it was well underſtood. You will ſee a full account of the proceſſes by which alum is manufactured, and of the materials employed in making it, in Mr. Fourcroy's Elements, under the article ALUM ; and in Mr. Chaptal's, where he deſcribes a new proceſs of his own. Bergmann alſo has given an inſtructive eſſay on the manufacture of alum.

Alum is generally manufactured from a ſoft laminated ſtony matter found in ſtrata, (and which bears ſome reſemblance to ſlate, but is ſofter, and commonly dark grey or black), called *alum ore ; aluminous ſchiſtus*,—*Schale*. It is compoſed of clay combined with ſulphur, and very often ſome bituminous matter. It hardly ever produces alum until after it has been burned with a very ſlow heat for a conſiderable time, which conſumes the bituminous matter, and changes the ſulphur into ſulphuric acid. It is accordingly burned by ſetting fire to very large heaps of it, which are covered up in ſuch a manner as to occaſion a ſlow and long continued inflammation and very gentle heat. There are ſome of theſe ores however, which, when formed in-

to heaps, take fire of themſelves, and burn ſlowly, without needing to be ſet on fire by means of fuel. And in ſome volcanic countries, they find materials which are already prepared for affording alum; in conſequence of their having been affected by the volcanic heat. In ſome few caſes alſo, the action of the atmoſphere alone, continued for a length of time upon ſuch materials, prepares them for affording alum, although they never have been ſet on fire. They are obſerved to be covered with a whitiſh duſt, which, when examined, is cryſtallized alum. When this is waſhed off, more forms in a day or two. Such matrices properly built up, ſo that the rain may waſh it off into gutters which lead to a ciſtern, afford a lixivium ready for boiling. There is at Hurlet, in the neighbourhood of Glaſgow, a ſtratum of ſhale which has been left in the old workings of coal mines, which, by the ſingularity of its ſituation, exhibits a wonderfully rich appearance. It is about ten inches thick, and, if cut out from a newly opened pit, does not yield an atom of alum: But lying in the open waſte for more than a century, it has decompoſed, and effloreſced. Moreover, there is above it a vaſt thickneſs of ſhale, which is too poor for working; but in the proceſs of time, has afforded, by filtration, enough to enrich the ſtratum below which effloreſces, and thus renews its waſte. The reſult of this has been, that each lamina of the ſchiſtus has not only ſeparated from the next, but the interſtice is filled with cryſtals continually increaſing; ſo that in ſome places the ſtratum of 10 inches has ſwelled ſo as completely to fill the ſpace from which the coal has been taken. I thought this ſingular fact not unworthy your notice.

In all theſe caſes, whether the alum ore has actually been ſet on fire and burned, or whether it be prepared by the long continued action of the air alone, the change produced is a combination of the ſulphur with vital air, and conſequently a change of it into ſulphuric acid, which acts on the clayey matter; after which, being ſteeped in water, it affords an aluminous liquor, which requires the addition of

ſome alkali, fixed or volatile, to prepare it for affording good cryſtals of alum by evaporation. The uſe of the alkali is partly to precipitate ſome calx of iron, which is commonly diſſolved in this liquor along with the alum, and partly, as is ſuppoſed, to ſaturate a portion of ſuperfluous ſulphuric acid. The cryſtals are firſt obtained of a moderate ſize, but are afterwards united into large maſſes by *roaching*.

Mr. Chaptal's proceſs is very refined and artificial. He obſerved that a gentle roaſting of clay diſpoſes it to a more ready union with the acid, eſpecially when this is in the form of ſteam. He therefore makes up the clay into ſmall balls, and roaſts them in an oven or kiln. One effect of this muſt be the driving out the water, and leaving the whole maſs very porous and acceſſible to the ſteam of the ſulphurous acid. The balls are now ſpread out on the floor and ſhelves of a great room, whoſe walls and cieling are covered with a fat luting impenetrable by the fumes. There is a furnace conſtructed in a corner of the room, in which ſulphur is made to burn in a manner which diſperſes it through the room in ſteams of the ſuffocating acid: The balls are penetrated, and the clay unites with it. When judged to be ſuperficially ſaturated with it, and alum formed in them, which requires ſome days, the room is opened, and the balls taken out and expoſed to the air under cover. The volatile acid becomes ſulphuric by extracting oxygen from the air, and diſſolves the clay, and the balls are then lixiviated. This manufacture is ſaid to be very profitable. (*Ann. de Chem.* vol. 3.)

The moſt inſtructive diſſertation that I have ſeen on this manufacture is, *Diſquiſitio Chemica de Confectione Aluminis, Auctore Guſtavo Suedilio, Upſal*, 1767.

The appearance and more obvious qualities of alum are more or leſs known to you. It is expoſed to ſale in large cryſtalline maſſes containing much water. By the application of heat it melts, ſwells, boils, and dries, and is then called *burnt alum*,—*alumen uſtum*, which has often a good effect on foul ulcers. In a greater heat, it does not

undergo real fuſion, but part of the acid is diſſipated. It diſſolves in cold water, but ſlowly, and in ſmall quantity. Hot water diſſolves it much better *. Its taſte is ſweetiſh, ſour, and aſtringent. It tinges ſome vegetable blues red. Theſe laſt qualities it derives from the acid, which is ſo little neutraliſed by the earth, or is preſent in the alum in ſuch quantity, that it is leſs changed in its properties than in other caſes. It is alſo united with the earth by a weak attraction. This appears from the facility with which alum is decompoſed by other ſubſtances; for not only the fixed alkalis, but calcareous earth, the volatile alkali and magneſia, if added to a warm ſolution of alum, cauſe efferveſcence and precipitation. The efferveſcence ſhews that the argillaceous earth is not diſpoſed to unite with the air, or with very little of it, if the ſolution be warm. This earth, when properly ſeparated from the acid and neutral ſalt, is purer argillaceous earth than any clay; and if it be precipitated from a cool ſolution, ſo that the earth may unite with a portion of the air of the alkali, it has the plaſtic qualities in the higheſt degree of perfection.

The French chemiſts have given a new name to this pure earth; *alumine* in French, and *alumina* in Latin. I confeſs I do not like this *alumina*. If a name is to be contrived, I would make it *argilla*.

Great quantities of alum are employed in the arts of dying, and in printing or painting of linens and cottons.

* It therefore readily cryſtallizes by cooling. In repeating Mr. Lowitz's experiment with a mixture of alum and nitre, I obſerved the whole alum cryſtallized in one form (octaëdral) which I had never ſeen before, it being commonly a mixture of both kinds. The obſervation of Mr. Lowitz naturally made me think it probable, that not only the alum alone was made to cryſtallize by touching the mixed ſolution with a cryſtal of alum, but alſo that the form of the cryſtal preſented would diſpoſe the whole to the ſame aggregation. The notions which I had of cryſtallization leads almoſt neceſſarily to this. I tried it, by preſenting to the ſame aluminous ſolution a cubical cryſtal, and the effect was as I expected. All were cubes or compoſites of cubes. I have found the ſame thing to happen in ſome other ſalts, which often appear in truncated cryſtals.

EDITOR.

To complete the natural hiſtory of the argillaceous earth, we may remark, that it is found in many other natural productions beſide the plaſtic earths or clays; in the *alum ore*, for example, which is indurated clay with ſulphur; in what is called *black chalk*, in which there is ſome inflammable matter which gives the blackneſs; in *ſlate*, which appears to have been formed from clay, indurated naturally by length of time and ſubterranean heat: There is a very great variety of ſtrata of this kind, which have different degrees of hardneſs and coheſion, and are more or leſs laminated like ſlate; all of which contain ſome of the argillaceous earth mixed with others; and they appear evidently to have been clays, which have been indurated more or leſs by ſome operations of nature, until many of them have acquired great degrees of hardneſs and durability. The general denomination for them all is SCHISTUS. The hardeſt of them are ſo cloſely concreted, that the ſtrata they form, called GNEISS, are among the moſt durable. The leſs hard conſtitute different kinds of SLATE, and the ſofter ones SHALE. In the neighbourhood of Geneva, and I ſuppoſe in France, ſome are called PIERRE DE CORNE.

The argillaceous earth is alſo a principal article in the compoſition of ſome of the hard ſtones, as we ſhall notice hereafter.

GENUS III.

HARD STONY BODIES.

IN this ſection I comprehend moſt of the ſtony ſubſtances called SILICEOUS, or FLINTY, by natural hiſtorians.

They are eminently hard, and they are unfuſible by the moſt violent heats of common furnaces or fires. Their hardneſs is ſuch, that they are not affected by the hardeſt ſteel, but on the contrary ſcratch it, and ſtrike fire with it. And they alſo ſcratch or cut glaſs.

The greater number of the ſtony ſubſtances which belong to this diviſion have alſo been called cryſtalline and vitreſcent,—*cryſtalline*, on account of their being oftener found in the form of regular and tranſparent cryſtals than other kinds,—and *vitreſcent*, as being the principal ingredients in glaſs, and more diſpoſed than any other earthy or ſtony matter to produce good glaſs with proper additions.

All the ſtony bodies of this diviſion contain a particular kind of earth, which I have had occaſion ſeveral times to mention, but not yet to deſcribe in this courſe. It predominates or bears a principal part in the compoſition of this order, and is at preſent conſidered as one more of the *ſimple elementary earths*. It has been commonly called the ſiliceous earth. The French chemiſts lately contrived the names for it, of SILICE in French,—and a barbarous term SILICA, in Latin.

We can eaſily extract it by a chemical proceſs from the ſtones of

of this diviſion; and the nature of the proceſs is ſuch, that the earth is obtained in the form of a precipitate, which is an exceedingly tender, light, and ſpongy earth.

The properties of it are theſe:

1*mo*, It is not diſſolved or otherwiſe affected by any acid, except the fluoric, which, when applied warm to it, and eſpecially in the form of vapour, not only diſſolves this earth, but volatilizes it.

2*do*, It is not fuſible in our moſt violent fires.

3*tio*, When mixed in powder with half its weight of potaſh or ſoda, or the carbonats of thoſe alkalis, the mixture can be melted eaſily in a ſtrong heat, and forms a perfect glaſs. It is even in ſome meaſure diſſolved or combined with potaſh, by boiling in a ſtrong watery ſolution of that ſalt. This experiment will not ſucceed with any ſiliceous ſubſtance reduced *mechanically* to a powder, however ſubtile. The utmoſt effects of mechanical diviſion and trituration fall infinitely ſhort of the ſubtile diviſion and attenuation which we obtain on many occaſions by chemical ſolution and precipitation. And this earth, in order to make it combine with an alkali that is diſſolved in water, muſt either be in this ſtate of the moſt ſubtile and tender powder, or it muſt be previouſly combined with a ſmall proportion of alkali in the dry way, or by fuſion.

This experiment and others enabled me to underſtand the nature of an earth which occurs in ſome parts of Scotland, in the form of a ſediment or mud, at the bottom of lakes of freſh water. There is a lake in Galloway in which it is found. Samples of it were brought to me a long time ſince, to know if it was a marle: I quickly perceived that it was not a marle; but the properties of it were ſuch, that for a conſiderable time I was at a loſs to give it a name. At laſt I found that the qualities of it were thoſe of the ſilex, or ſiliceous earth, and that it was principally compoſed of this earth. It may therefore be named *limus ſiliceus*, or *ſilex limoſa*. It is undoubtedly depoſited in thoſe lakes, in conſequence of the demolition and decom-

poſition of ſtones and rocks, which contain it in the higher parts of the country, from which thoſe lakes are ſupplied with water.

This completes the liſt of the earths that are at preſent conſidered as the moſt remarkable and moſt abundant *elementary earths*. They are ſix in number, diſtinctly known, namely, the *calcareous earth* or *lime*, *magneſia*, *barytes*, *ſtrontites*, *alumina* or the *argillaceous earth*, *ſilica* or the *ſiliceous earth*.

We have been lately informed of a very few more lately diſcovered, which appear to be ſimple earths, and yet are different from any of theſe; but they are produced by nature in very ſmall quantity, and have only been found in the compoſition of ſome particular and rare ſtony concretions of a ſmall ſize; *nor have they yet been ſufficiently examined.* I do not, therefore, think it proper at preſent to take up your attention with them. You will ſee mention made of them in the new ſyſtems of mineralogy which I lately recommended to your notice.

To return to the conſideration of the hard ſtony bodies.—They appear to have their hardneſs more or leſs from the ſiliceous earth, or ſilica, in their compoſition; but they contain it, however, in different proportions, or in different ſtates of purity. I ſhall firſt enumerate thoſe which contain it in largeſt quantity, or in a ſtate which approaches the neareſt to purity. Theſe are,

1. Crystal, or rock cryſtal, which is tranſparent.

2. Chalcedony, which has an imperfect tranſparency reſembling that of whey.

3. Quartz, which has a whiteneſs like that of milk and water, and ſhattered appearance, and breaks with an uneven ſurface, not a plated ſtructure like ſpar. It is abundantly produced by nature.

4. Agate, in which the ſtony matter is diverſified with ſtreaks and ſpots, whitiſh, or of other colours.

5. Flint, ſilex, which has an uniform dark colour like dark coloured horn, but becomes white in the fire.

6. An exceeeding fine looſe earth found at the bottom of ſome of our lakes in the mountainous parts of this country. It may be called *limus ſiliceus, or ſilica limoſa.*

Theſe varieties of hard ſtones contain the ſilica the moſt abundantly, or moſt approaching to a pure ſtate.

But in many of the other ſtones of this order it is very impure, or mixed with a large proportion of other matter.

When iron is mixed with it in ſuch quantity as to colour it ſtrongly, and render it opaque, it forms JASPERS of various colours. Theſe are diſtinguiſhable from flint by breaking without the ſmalleſt luſtre, like dry clay, and void of all tranſparency. Or if the quantity of the iron is leſs, and the ſtone is ſemi-tranſparent, and of a red colour, it is named CARNELIAN, from the reſemblance of its colour to that of raw fleſh.

Theſe are the principal appearances of the hard ſtony matter.

But it may alſo be proper to give a general view of the various ſituations and collections of the hard ſtones in nature.

1*mo*, They are found conſtituting numerous and extenſive ſtrata; and thoſe which are the moſt abundant, are the ſtrata of common ſand and gravel, and ſand-ſtone, and gravel-ſtone, which are very numerous and common, and of great extent. The origin of ſand and gravel was formerly explained.

Some ſands are white, or free from any colour, and are totally compoſed of ſmall grains of cryſtal or quartz, ſuch as the ſand from Lynn in Norfolk. It is the fitteſt of all for fine glaſs.

The greateſt number of ſands, however, are variouſly coloured, by the admixture of other matter with the ſiliceous in the compoſition of many of the grains. And ſome are perfectly opaque, and dark coloured, and even black, from the large proportion of iron.

2*do*, GRAVEL is in many places of the ſame nature as common ſand, and is found in the compoſition of ſtrata, either by itſelf, or more commonly mixed with ſand or clay in different proportions. It con-

ſifts principally of the ſame kind of matter as the ſands, only in larger grains or maſſes, more irregular in their form and ſize, and more coarſe and opaque by the more plentiful admixture of other earthy matter with the ſiliceous earth. Gravel is, however, of very different kinds in different places, and it muſt be ſo, as being formed of the hardeſt fragments of the ſtones of the country in which it is found.

3tio, SAND-STONE is the third kind of ſtratified matter, which I ſaid is found in great abundance; and which, in moſt places, is compoſed of hard ſtony materials. It has evidently been produced from common ſand concreted together.

When the ſand of which it is compoſed does not cohere too ſtrongly, this ſtone is employed in buildings which are erected with hewn ſtone, and it is then called FREE-STONE. All the free-ſtone of this country is compoſed of ſiliceous ſand, and is therefore remarkably durable; and we have plenty of it. The ſand of which it is compoſed was firſt collected and waſhed clean by water in the long lapſe of time, and was afterwards cemented together by ſome operation of nature. The proofs of this are, an undulated appearance which often occurs in the ſurfaces of its ſtrata, and which is exactly ſimilar to the undulated ſurface formed on the ſands of the ſea-ſhore, or of lakes, by the action of the waves. And we often find alſo in the ſtrata of ſand-ſtone the relics of ſea productions. There is, in particular, a very remarkable object found in many free-ſtone quarries in this country. The ſtone itſelf is obſerved to take the form of a plaited (not twiſted) rope, of conſiderable thickneſs, and generally flattiſh, the greateſt diameter being horizontal. In the different plaits of it there is a ſmall indentation, and the plaits are moſt regularly diſpoſed. When broken acroſs, it has a ſort of core, black and ſoft, and fibres are obſerved to go out from this to the indentations on the ſurface. This object is ſometimes of great extent, traceable through the ſtratum in a horizontal direction many yards, varying in diameter from half an inch to five or ſix inches, and ſome-

times ſending off branches. An example of it was ſeen lately in a quarry on the ſea-ſhore near Muſſelburgh, which reſembled the trunk of a vaſt tree ſending out branches in all directions.

Sand-ſtone is of very various hardneſs. In ſome the ſand has but a weak degree of coheſion. In others the grains are ſo cloſely and ſtrongly coherent, that the ſtone has the appearance of ſolid flint, and cannot be wrought as a free-ſtone.

4*to*, The ſtrata of what I called gravel-ſtone have been formed in the ſame manner as ſand-ſtone, only that gravel is intermixed with the ſand in the compoſition of the ſtone. From its appearance this ſtone is named by the Engliſh *pudding-ſtone*; and the name has been adopted by foreigners.

Such are the ſtrata, principally or totally compoſed of the hard ſtony bodies. There are alſo ſome kinds of rock in which more or leſs of them is contained, as granite, to be ſoon deſcribed; and the more compounded kind of rock which abounds in this country, named WHIN-STONE, ſome kinds of which are a more coarſe and compound granite. The whin-ſtone often contains nodules and pebbles of all different ſizes, ſome of which are hard ſtones.

The ſchiſtuſes alſo, or indurated argillaceous ſtrata, often contain a large proportion of quartz irregularly intermixed through them.

The hard ſtones conſtitute therefore a great part of the materials of many ſtrata and rocks. They are alſo found often in *veins*, or otherwiſe interſperſed through rocky or ſtratified matter. The ſpecies moſt frequently found in this ſtate is quartz; but we alſo find occaſionally, cryſtal, chalcedony, agate, jaſper, and flint.

There are great quantities of flint in England, interſperſed in a very irregular manner through the calcareous ſtrata of chalk and limeſtone, traverſing and running through them in different directions. As found in chalk, it is more eſpecially named *flint*; as occurring in limeſtones, it is named *chert* by the Engliſh.

From the appearance of this matter, as found in this ſtate, there

is reaſon to be convinced that it has been introduced in a very fluid ſtate, or that it has been produced in theſe ſtrata by the action of ſome very fluid matter which has penetrated them. The proof of this is, our finding ſhells, lithophyta, and other marine productions, originally calcareous, but which are now completely penetrated by this ſort of matter, and ſeemingly converted into flint or agate, without loſing their external form. The ſame fact is further eſtabliſhed by the quantities of foſſil wood penetrated and petrified with this matter, found in many parts of the world. It is found in all ſtates, from that of ſtony wood, ſtill combuſtible, to that of pure flint.

It alſo deſerves notice, that the nodules of flint found in chalk and lime, often in very ſtrange forms, are not ſimply lying there, but ſeem forming, or elſe decaying, in that ſituation, being always ſurrounded by a cruſt, which changes gradually from a calcareous to a ſiliceous nature.

Another curious fact relating to this ſtony ſubſtance is, that maſſes of it are ſometimes found which include water perfectly incloſed in the hard ſtone. This has been obſerved in cryſtal, in common flint, and in agate.

In whichſoever of theſe ſtates the hard ſtones are found, when maſſes of them occur that are not ſolid, but have vacuities within them, in theſe we find their matter cryſtallized, and very often into remarkably regular and tranſparent cryſtals. Such are often found in hollows of veins, and of pebbles. They are generally columns of ſix ſides, terminated by a ſix-ſided pyramid: Or ſometimes they are pyramids alone. All theſe cryſtals are chiefly found in cavities of veins, or of hard ſtones.

I have yet to mention one other ſtate or condition in which the ſilica has been found, and that is, diſſolved in water. There is one very remarkable example of this in Iceland, particularly at the cele-

brated *Geyſer*, where ſome hot ſprings contain ſo much as to form ſiliceous petrifactions.

Theſe are the different forms and ſtates in which we find the hard ſtony bodies. We are now to take notice of their chemical properties.

The pureſt kinds, or thoſe which contain the moſt of the ſilica, when they are expoſed to a ſtrong heat, generally become opaque, white, and brittle. But they ſuſtain the moſt violent heat without melting, or being ſoftened by it. We can melt them, however, eaſily and perfectly, with fixed alkaline ſalts, with which they unite in the fire to form a perfect and workable glaſs. By workable glaſs, I mean a glaſs, which, while it is allowed to cool from its melted ſtate, continues ſoft and ductile a conſiderable time, and paſſes through all the degrees of ſoftneſs before it become hard and rigid. During theſe ſtates of ſoftneſs it has great ductility, and can be wrought or moulded to any form. Glaſs that is workable in this manner is one of the moſt valuable productions of chemiſtry.

All good glaſs contains ſiliceous matter and a fixed alkali as its only or principal ingredients. And ſand, when it is compoſed of pure, or nearly pure ſiliceous matter, is preferred to the other forms of the hard earths, on account of its being eaſily mixed with the alkali and other materials, without requiring the expenſive operations that would be neceſſary for reducing to powder, or to ſmall grains, the hard maſſes of other ſiliceous matter.

In the compoſition of ſome kinds of glaſs, other materials are added to the ſand and alkali; but the effect of theſe other materials is chiefly to increaſe tranſparency, or to affect the colour, or to diminiſh expence.

The ſiliceous matter and alkali muſt bear certain proportions to one another to make good glaſs. If the alkali be deficient in the due quantity or goodneſs, the ſiliceous matter is not completely diſſolved, and the glaſs not ſufficiently tranſparent. If the alkali is redundant,

the glaſs is liable to be corroded, or to have its ſurface tarniſhed by damp air. By increaſing the alkali to twice the weight of the ſiliceous matter, we make a ſort of glaſs which diſſolves completely in water. Thus is produced what is called the *liquor ſilicum*, which coagulates into a jelly by expoſition, or by the admixture of acid, or by volatile alkali (according to Neumann). This is the chemical proceſs by which we obtain the pure ſiliceous earth.

Although glaſs turns out very faulty when it thus contains an over proportion of alkali, it is however found neceſſary, in making good glaſs, to uſe rather more alkali than what is barely ſufficient to melt the ſand; and then, by a continuance of the fire, to evaporate the ſuperfluous quantity. Thus we are more certain of perfect ſolution or fuſion of the ſiliceous matter.

It is alſo common to uſe a quantity of nitre in place of part of the fixed alkali, in making the finer kinds of glaſs, to conſume the inflammable matter; and borax likewiſe is frequently added in ſmall experiments. A mixture of theſe ſalts with a very pure or choſen ſand, or other ſiliceous matter, produces glaſs of uncommon brightneſs and tranſparency, which can be coloured by addition of metallic ſubſtances, and gives thoſe imitations of the gems which in this country are called *paſtes*.

The author who has given the beſt account of the art of making glaſs of different kinds, eſpecially the fine and coloured glaſſes which are made in imitation of the gems, is Kunkel, in an edition he gave of *Neri's Art of making Glaſs*.

In the finer kinds of glaſs, therefore, the ſiliceous earth is combined chiefly with a pure fixed alkali, and brought into a vitrified ſtate by means of that ſalt; for when nitre is uſed, it is changed into pure fixed alkali. The calces of lead, as they were named formerly, ſuch as white-lead, and red-lead, are employed in the manufacture of the Engliſh FLINT GLASS, ſo remarkable for its pure tranſparency, which fits it for being cut into facets, and other ornamental forms, and gives it

remarkable brilliancy. In making the coarſer and cheaper kinds, as bottle glaſs, window glaſs, and the like, they do not uſe a pure alkali, but take the aſhes either of land vegetables, or kelp, or barilla, which are the aſhes of marine plants, with the ſalts they contain. And theſe aſhes are mixed with ſand, or other ſiliceous matter, to make ſuch kinds of glaſs. In this caſe, the earthy part of the aſhes, which in part conſiſts of alkaline earths, aſſiſts the fixed alkali in bringing the ſiliceous matter into fuſion, and enters into the compoſition of the glaſs. It is not nearly ſo powerful a ſolvent, however, as the pure fixed alkali, and therefore we muſt employ, in the compoſition of ſuch glaſs, a ſmaller proportion of ſiliceous matter than when the glaſs is made with pure alkali. And it is alſo neceſſary to frit the materials before they are melted in the pots in which the glaſs is formed. This is expoſing the materials in a furnace, generally adjoining to the working furnace, and deriving its heat from it. This is a reverberatory, where the materials are ſpread out on its hearth, and kept roaſting for many hours, or even days, with a red heat. This is neceſſary, for two reaſons: 1*ſt*, and chiefly, to conſume completely all remains of the inflammable matter of the aſhes. 2*dly*, To expel from the fixed alkali and aſhes ſome part of their fixed air.

The earthy part of the aſhes of vegetables always contains ſome iron, which gives a green colour to ſuch glaſs. I muſt obſerve, that the coarſeſt kind of glaſs, on account of the large quantity of earthy matter which it contains, and the penury of ſalt, is fitted for giving what is called Reaumur's porcelain of glaſs. This is a curious change produced on thoſe hard glaſſes, by long expoſition to a red heat in contact with ſand, gypſum, and other ſubſtances. The glaſs gradually acquires a cryſtalline ſtructure, formed in fibres which are perpendicular to the external ſurface. The longer the piece is continued in that ſituation, this ſingular arrangement penetrates deeper, till the growth from each ſurface meets in the middle of the thickneſs. After this, if much longer continued, the fibrous ſtructure becomes

ſomewhat granular, and the grains in the middle become large and detached, and ſometimes the piece ſeparates in the middle of its thickneſs. When this change is completed, and no more than completed, the glaſs has greatly changed its nature with regard to the effects of heat. It is now infuſible by the heat of a glaſs-houſe furnace, and will bear to be plunged into water when red hot. It is alſo extremely hard, and cannot be ſcratched by the hardeſt file. Mr. Reaumur diſcovered this by accident, and recommends this preparation for retorts, mortars, and other chemical veſſels, where theſe qualities are of importance.

It is a curious circumſtance in glaſs, eſpecially the coarſer kinds, that, when allowed to cool very ſlowly in great maſſes, it takes a cryſtalline opaque form. When broken, it would be taken for a natural foſſil. The ſtructure is fibrous, and the fibres all converge to centres, but are commonly interrupted by others converging to other centres. The whole is extremely like, and may be miſtaken, even by a foſſiliſt, for a zeolite. Sometimes we find, in large lumps of green glaſs, little round balls like pin heads, or peaſe, of the ſame dirty white colour. Theſe, when examined by a microſcope, are found to be cryſtallizations of the ſame kind,—the fibres all ſtanding inwards, perpendicular to the ſpherical ſurface. Now, looking at the confuſed cryſtallization of the great maſſes juſt now mentioned, we ſee that they affect the ſame arrangement, and we can trace the circumference of each ſphere, of which theſe radiated cryſtals are a portion. By the way, this appearance puts an end to the doctrine of thoſe who aſcribe all cryſtallization to watery ſolution. Here we ſee it produced altogether by heat. Indeed we know that many metals, and ſulphur, always cryſtallize in cooling, and will congeal in no other way.

After this digreſſion on the nature and manufacture of glaſs, which its importance will ſufficiently juſtify, it is proper to conſider a little more the union of the alkali and ſiliceous earths. I obſerved that they not only united by melting, but even by boiling the earth in a watery ſolution.

When the liquor ſilicum is mixed with an acid, the earth is precipitated in an impalpable powder, which will be completely rediſſolved by adding more acid, and again precipitated by adding more alkali; and thus may be repeated as often as we pleaſe. But there are differences in this reſpect which are remarkable. The Chevalier Dolomieu obſerved that when quartz was precipitated in this way, it would not be rediſſolved by acid, if kept in the ſtate of a precipitate even for a few hours. This, with ſome other peculiarities of the quartz, attracted his attention. Quartz emits a very peculiar ſmell when rubbed or ſtruck by another bit of quarz, and emits much light. If the duſt ſtruck off be examined with a microſcope, particles of it are found ſcorified, and ſpungy. Quartz frothes when melted on charcoal. He therefore ſuſpected that it contained elaſtic and inflammable matter.

He mixed 10 drachms of quartz with a ſolution of cauſtic alkali in a retort, joined to a pneumatic apparatus. By gradually raiſing the heat to the grateſt intenſity that his retort would bear, he expelled from it, 1*ſt*, 22 inches of azotic gas; 2*d*, 12 inches of hydrogenous gas; 3*d*, 22 inches of airs, of which 16 were carbonic acid, and the reſt a mixture of azotic and hydrogenous gas. The reſiduum was, in ſome caſes, a ſpongy glaſs, and in others ſolid and green coloured.

He thinks that quartz, when diſſolved in acids, has quitted the azote and hydrogen; and when precipitated by alkali, has regained it by decompoſing the water. When deprived of theſe airs, it has an attraction for acids, but loſes it when reunited to the azote and hydrogen and carbone, as lime has its attractions diminiſhed by its union with fixed air.

Dolomieu ſubjoins to theſe experiments ſeveral ingenious obſervations on the ſiliceous earths, and ſubſtances which contain them, particularly the gems. Although he advances ſome opinions which ſeem to me very unwarranted by experiment, his obſervations are curious and intereſting. You will find an abſtract of his diſſertation in the Journal de Phyſique, May 1772.

GENUS IV.

FUSIBLE STONES.

THE ingenuity and induſtry of the modern chemiſts and natural hiſtorians, particularly of Margraaf, Woulfe, Bergmann, Scheele, Kirwan, and others, have diſcovered that the natural earthy or ſtony ſubſtances which I comprehend under the titles of FUSIBLE and FLEXIBLE, do not contain any ſimple elementary earth that is different from thoſe ſix we have already deſcribed.

The fuſible and flexible ſtones are all compounded of two or more of theſe ſix earths, intimately united and incorporated together.

You will find in Bergmann's Opuſcula, and in Mr. Kirwan's Mineralogy, an account of the proceſſes by which earths and ſtones may be analyſed, and the ſimple earths of which they are compoſed, ſeparated exactly from one another. We cannot deſcribe theſe proceſſes here. They are too complicated and tedious to be a fit ſubject for a lecture. A perſon who would make himſelf maſter of them muſt ſtudy them at home, and at leiſure.

Profeſſor Bergmann, in his *Outlines of Mineralogy*, and Mr. Kirwan, in his valuable work on the ſame ſubject, have formed their arrangement of the earthy and ſtony ſubſtances, and their diſtinctions of them, from the prevalence of the ſimple earths moſt abundant in the

compoſition of each; and for this reaſon they have no diviſions or claſſes which correſpond to theſe two laſt of mine.

Their method, however, aſſembles together things ſo very unlike to one another in every other reſpect, that I have not choſen to follow it. The greater part of the gems, for example, the ruby, emerald, topaz, and others, are put into the ſame claſs with the clays, on account of their having more of the argillaceous than of any other ſimple earth in their compoſition.

But a perſon who wiſhes to have ſome knowledge of the riches and variety of nature in this part of her works, ought ſurely not to confine his attention too much to that point. There are many other differential qualities of her productions, which are more eaſily perceived, and more ſtriking; and therefore more proper to be attended to in diſtinguiſhing and arranging them, and in giving general views of them. And this is the reaſon that has induced me to prefer the method I follow in giving a general account of the earthy and ſtony bodies. And I muſt premiſe that there is ſcarcely any method for theſe ſtones that is not very imperfect. This reſults from their compound nature. Accordingly, it is extremely difficult to claſs a ſpecimen that comes in our way by means of the deſcriptions given by the foſſiliſts. Nor are they agreed in their denominations: What one calls a granite, another calls a porphyry; and a third calls it a trap.

The natural ſtones which I think it is proper to aſſemble under the title of *fuſible*, are of ſix kinds:

1. Feldt ſpat, or felt ſpar.
2. Porphyry.
3. The garnat.
4. The ſtony matter called ſchoerl or ſcherle by the Germans and natural hiſtorians, and cockle, by the Engliſh miners.
5. The zeolite.
6. The lavas, baſaltes, pumice, and other fuſible matters, which have evidently been thrown out of the bowels of the earth by volcanic

fires and explosions; or which appear to have been formed and accumulated by them under the surface.

The first of the fusible stones, therefore, is the FELDT SPAR, the appearance and qualities of which are these:

It is a stone generally less transparent than quartz: Some kinds are as white or free from colour. More commonly, however, it has a reddish tint or flesh colour. In hardness, it is nearly equal to the hard stones, and therefore strikes fire with steel. When it is broken we can always perceive by the reflection of the light from its surface, that it has a plated structure, and it has a disposition to be broken into rhombic fragments. These two qualities are never found in quartz.

FELDT SPARS are,

1*mo*, The most common, of a reddish colour.

2*do*, The white.

3*tio*, The crystallized.

4*to*, Crystallized and transparent,—*adularia*.

When feldt spar is exposed to the action of heat, it first becomes more brittle and pulverable; and afterwards, if the heat be increased to a violent degree, it melts into a viscid glass, which is white and semi-transparent; on account of which property, and some others, it is excellently fitted to be an ingredient in the composition of porcelain.

It has been analysed by Mr. Woulfe, Professor Bergmann and others, and the definition given of it by Bergmann, in consequence of this analysis, is,

"Siliceous earth united with argillaceous earth, and a small quan-
"tity of magnesia and sometimes barytes." The proportions have been found very different in different felt spars, or in the different analyses that have been made of them, of which you will find a comparison in Mr. Kirwan's Mineralogy. From the whole he concludes, that any compound of silica and alumina, in which the silica predo-

minates, and to which a ſmaller proportion of lime and magneſia, or of lime, magneſia, and barytes accedes, ſo as form a compound, fuſible in a ſtrong heat, may conſtitute a felt ſpar. The magneſia and alumina may be exactly ſeparated from one another by diſſolving them in the muriatic acid, and precipitating by carbonat of ammonia. The whole of the alumina is precipitated, and the magneſia remains diſſolved in the form of an acidulous carbonat.

Feldt ſpar abounds in the compoſition of the rock or ſtone called granite, and is the diſtinguiſhing ingredient in that ſtone. Granite has its name from being compoſed of angular grains of various ſizes, in the different varieties of this ſtone; the greateſt number of which grains are felt ſpar; the reſt quartz and mica, which we ſhall ſoon deſcribe.

The granites form ſome of the higheſt and moſt extenſive chains of mountains in many parts of the globe, being in general very durable ſtones, though ſome of them are not ſo remarkable for durability. And, as we never find any relics of marine productions in them, they are conſidered by many as original or primeval ſtones, and their formation as long prior to that of any ſtratified matter. But my friend Dr. Hutton, having viſited ſome parts of this country where granite is found, and examining with attention thoſe places where the granite was bounded by the ſtratified matter, or came in contact with it, he found the ſtratified matter, which was of the hardeſt and moſt durable kind, ſplit and broke in thoſe places in a remarkable manner, and the granite conſtituting or forming veins in it; that is to ſay, that the granite had penetrated into the fiſſures and rents of the ſtratified matter, and had filled them up completely: ſhewing therefore that the ſtratified matter had, in this caſe, exiſted firſt, and that the granite was applied to it with violence and in a fluid ſtate. Some of the hardeſt granites that are known are rendered extremely friable by a very moderate heat, even that of a ſmall bundle of ſtraw burning in contact with them.

Feldt ſpar, beſides entering thus largely into the compoſition of granite, occurs alſo ſometimes by itſelf in veins.

The ſecond ſpecies of fuſible ſtone is PORPHYRY. It is of various colours, of which a dirty browniſh green is the moſt common. It is alſo of a deep red, black, and ruſty brown, and ſometimes of a dark grey. All of them have ſpots, and the ground is compact, and breaks with ſomewhat leſs luſtre than marble, but more than flint. The ſpots in it are feldt ſpar. Its hardneſs is greater than that of marbles, but inferior to that of hard ſtones, and it is eaſily fuſible.

It forms large maſſes and rocks in the places in which it is found; and ſome kinds of it have beauty, by their colour and capability of poliſh; but theſe are rare. The Upper Egypt alone ſupplied Rome with fine porphyries.

The third kind of fuſible ſtony matter, the GARNAT, is very commonly cryſtallized into roundiſh polyhedral maſſes of a ſmall ſize, and is generally of a deep red colour, and tranſparent. In ſome of theſe ſtones, the deep red colour is accompanied by great tranſparency and brightneſs; though in the greateſt number it is obſcured, by innumerable flaws and cracks, or the admixture of other earthy matter. By chemical analyſis a conſiderable quantity of iron can be extracted from the deep-coloured garnats, and to this metal the colour is imputed. But ſome ſpecimens of this ſtone contain little or no iron, and ſuch have very little of the red colour.

It is found, and appears to have been formed, in ſtones that abound with mica or with feldt ſpar. It has its name, *granatus*, from its reſemblance to the pulpy ſeeds of the granate apple, or granate fruit.

The fourth of the fuſible ſtony ſubſtances is named SCHOERL, and is found in many compounded or mixed ſtones which never are of the ſtratified kind, but are ſome of the ſpecies of what I call rock.

The ſchoerl appears on theſe ſtones in the form of ſeparate grains or maſſes, always cryſtallized into extended columnar forms, or into fibrous or plated maſſes. Sometimes it forms groups of ſtraight fi-

brous cryſtals, like the briſtles of a bruſh, or even more ſlender than fine hair; and in ſome caſes is found in this form traverſing tranſparent cryſtals. Another ſingular form is the *croſs ſtone*, conſiſting of two of theſe cryſtals croſſing each other, not as adhering, but croſſing through the centre, ſome perpendicularly, and others in an angle of 60 degrees. A fine ſpecimen was ſeen in this country in cryſtals, which were hexagonal priſms, ſome of them almoſt an inch in diameter, and ſome inches long. They were deeply indented tranſverſely, as if made up of plates not all of one ſize. Examining ſome fine hair-like cryſtals in my poſſeſſion with a microſcope, I found them of the ſame ſtructure. It is often black and opaque, and ſome of theſe varieties are named *hornblend*.

Many kinds of it, however, are tranſparent, and have even the brightneſs of gems, with a green colour more or leſs deep. The colour and opacity in this ſtone always proceed from more or leſs of iron. The moſt remarkable of the ſchoerls is the *tourmalin*,—remarkable for its primitive and permanent electricity and electric polarity, perfectly analogous to magnetiſm.

All ſchoerls melt without difficulty in a ſtrong fire, and form a black or dark coloured vitrified maſs.

The fifth kind of fuſible ſtone in the enumeration I gave, was the ZEOLITE. It was firſt diſtinguiſhed and characteriſed by Cronſtedt. It occurs in general in the form of ſmall maſſes involved in rocky ſtones, or forming veins in ſuch ſtones. That part of the rock of Arthur's Seat which ſhews a tendency to the form of ſix-ſided columns, or priſms, contains ſmall veins of zeolite harder than common.

The zeolite is always cryſtallized, or ſhews ſome regular external form or internal arrangement of its matter. Some of theſe forms are the moſt wonderful and beautiful of all that have been obſerved in the mineral kingdom. Some are hollow, and are formed within into tranſparent or whitiſh cryſtals; ſometimes ſlender and long, like fine

briſtles, in diverging bunches; and ſometimes even theſe briſtly cryſtals of the zeolite pervade chalcedony, and ſometimes ſmall ſiliceous cryſtals like grains of corn are involved in them.

The chemical qualities of the zeolite are, to melt in the fire, or by the heat of the blow-pipe, with remarkable facility. And moſt kinds of it ſwell at firſt into a ſpongy maſs like froth, or ſometimes as borax does in its watery fuſion. It is from this circumſtance that it gets its name. Indeed, they contain a conſiderable quantity of water in their compoſition; but that cannot be the cauſe of this fuſion. But after this, by increaſing the heat, the zeolite contracts again, and melts more perfectly, either into a clear and bright glaſs, or ſome kinds of it, which are more difficultly melted, form only a white opaque glaſs, or white enamel.

When diluted nitric acid is applied to the zeolite, this ſtone is diſſolved into a clear liquor, which after ſome time becomes a jelly.

Theſe chemical properties of it were diſcovered by Mr. Cronſtedt. But my friend Dr. Hutton proceeded farther in this experiment; and by examining the ſolution, and the gelatinous matter formed in it, he diſcovered that the zeolite is a compounded ſubſtance, and contains a fixed alkali combined with ſiliceous and with argillaceous earth. The proportion of the alkali to theſe earths is different in the ſeveral varieties of this ſtone; and this is the reaſon of the different degrees of fuſibility which we find in them. They all contain a great quantity of water.

The laſt kind of fuſible earthy and ſtony ſubſtances are thoſe which are thrown out, or formed, by volcanic fires. Of theſe there is a conſiderable variety. We find among them what are called Lavas and Pumice, and what are called Ashes.

The lavas are very various. Some parts of them are black and perfectly vitrified, reſembling the darkeſt and coarſeſt kind of glaſs. Generally, however, they are a mixture of earthy ſubſtances, which have not been brought to a ſtate of perfect fluidity. Some of the

materials only, were fluid when they came out of the volcano; and the whole had the conſiſtence of thin mortar, or ſometimes has been more fluid. When it cools, it has not an uniform or glaſſy texture, but is compoſed of particles and fragments of many different kinds, cemented together by the matter which was melted.

The fluidity of lava appears to me to depend on latent heat, combined with the materials by the long continued action of ſubterranean fire. While they are ſtill flowing, their heat is not very intenſe. (*Dolomieu Journ. de Phyſ.* 1793). Yet they retain part of this heat a long time, with ſome degree of fluidity or ſoftneſs. A lava, erupted in 1614, continued to move for ten years, and in that time ſlipped downwards about two miles. It was probably ſoft below; and as it lay on a ſlope, the indurated maſs above could ſlide a little way *.

Moſt natural hiſtorians are now of opinion that the rocky ſtone, of which there are many varieties in this country under the name of WHINSTONE, but in other places called TOADSTONE, RAGSTONE, or ROWLEY-RAG, and alſo TRAP and BASALTES, and by other names, is of the ſame nature with lava, and belongs to this diviſion of volcanic matter,—a matter which has been melted by ſubterranean fire. Dr. Hutton, however, makes a diſtinction between many, or moſt of theſe ſtones or lavas. He conſiders the term lava to be properly applicable to that melted matter only which has been thrown out by volcanoes, ſo as to flow down their ſides, or along the ſurface of the earth. But there cannot be a doubt, that the ſame fires muſt produce, at a great depth, large quantities of melted matter, which is never thrown out, but continues melted a long time, and is driven by the immenſe force of the explosive matter in lateral directions, forcing its way between the ſtrata which are around, or penetrating into the rents and fiſſures of theſe; and thus forming what we call dykes, or in other caſes, flat and extended maſſes of unequal thickneſs, ſuch as Saliſbury Rock,

* The ſpongy texture of the indurated matter muſt greatly retard the emerſion of the latent heat, and conſequently the congelation below. EDITOR.

and many others that are around it, and the toadſtone of Derbyſhire *.

Whinſtone is called *baſaltes*, when it is ſplit into columns or priſms, moſt of them ſix-ſided, and ſtanding in cloſe contact together, generally upright, though ſometimes inclined to the horizon, and even bent.

There are famous examples of this in the Giants' Cauſeway in Ireland, and in the iſland of Staffa, and other iſlands and rocks on the weſt coaſt of Scotland. And there is a tendency to it on the ſouth-eaſt ſide of Arthur's Seat here, beſide many examples on the continent.

This columnar appearance ſeems to ariſe from a kind of ſhrinking as the heat which gave it the imperfect fluidity gradually abates. I was informed by a gentleman who viſited Iceland not long after the late eruption of Hecla, that the inhabitants ſhewed him extenſive maſſes of lava of former eruptions, which were not thus ſhivered, when they had cooled ſo much that they could be approached, but that year after year, the regular columnar diviſions appeared more evident: And at the time the gentleman ſaw them, they were very diſtinct baſaltes. We obſerve an appearance very ſimilar to this in common ſtarch, which always ſeparates by ſhrinking into pentagonal and hexagonal columns.

The opinion that this ſtone, and whinſtone in general, has been formed from melted ſubterraneous matter, is founded on the ſimilarity of its appearance to that of many lavas; and there is a ſimilarity too in their conſtituent ingredients. And further, the lavas of ſome well known and now exiſting volcanoes, have been found in ſome parts of them formed into theſe pillars; as the Chevalier Dolomieu obſerved in the lavas of Ætna.

* A dyke of this kind pervades the coal ſtrata in Newcaſtle Moor; and it has charred the coal on each ſide of it to the diſtance of ſeveral yards.

EDITOR.

In baſaltes and whinſtone we commonly perceive many particles which have a plated ſtructure or extended priſmatic figure, more or leſs reſembling ſchoerl. The colour of the ſtone is commonly grey or black, or dark red; but ſometimes, though rarely, light grey, or whitiſh.

There is a conſiderable variety of the ſtones or rocks which belong to this ſpecies, or may be included in it; and moſt of them are not formed into columns, but are in general ſplit into oblong angular maſſes, which are often upright, as in Saliſbury Rock; but in ſome caſes inclined to the horizon. Some approach very nearly in nature to granite; others as nearly to porphyry. The rock of the Calton Hill is a ſtone of this kind, which has the nature of porphyry in ſome parts of it. The rock of the Baſs approaches to granite.

They often contain nodules, or ſmall maſſes of ſtony matter, different from that of the rock itſelf. Theſe ſmall maſſes are either ſiliceous, or calcareous, or barytic, or zeolite, or a collection of ſome of theſe ſtony bodies in the ſame maſs. The greater number of agates, and eſpecially the ſmall ones, called Scotch pebbles, are ſmall ſiliceous maſſes, which have been formed in rocks of this kind; and are found in the gravel and rubbiſh produced from the decay of theſe rocks.

The toadſtone, of Derbyſhire, is a whinſtone containing nodules of calcareous matter.

It is always in theſe whinſtone rocks too, and particularly the baſaltic kind, that zeolite is found, either in nodules or in veins.

Anciently, whinſtone and other fuſible ſtones appear to have been employed, in this country, to conſtruct walls or ramparts round little camps, or ſtrong poſts, into which the inhabitants retired when invaded by an enemy. And they appear to have been cemented by fire,—the external parts, on both ſides of the wall, being melted into an imperfect ſlag. There are ruins of ſuch works in different parts of Scotland; the conſtruction of which muſt have been long prior

to any tradition that now remains, or to the uſe of lime. A deſcription of ſome of them has been given in the Tranſactions of the Royal Society here, by my colleague, the Profeſſor of Civil Hiſtory.

Pumice is the next volcanic matter. It has the appearance of having undergone very perfect fuſion. The moſt remarkable quality of it is its ſpongineſs. It has nearly the contexture and appearance which glaſs would have, were it wrought up into a froth while it is cooling. The Chevalier Dolomieu, in his account of the *Iſles Cyclopes*, a cluſter of iſlands near Sicily, has given the natural hiſtory of pumice. And I have obſerved ſome facts and phenomena, occurring in ſome of the arts, which may ſuggeſt conjectures of the way in which it is formed, viz. what appears in ſlags of lead, and alſo ſlags of iron haſtily cooled.

The laſt volcanic matter, called Ashes, is a ſort of gravel and ſandy duſt, compoſed of vitrified and ſpongy particles of all ſizes; and is undoubtedly a ſort of rubbiſh, into which different materials are changed, when ſoftened by the heat and expoſed to the violent concuſſions and exploſions which happen in the bowels of the mountains, or during eruptions. It is ſometimes thrown up to a very great height in the air, and is then carried away by the winds, ſo as to fall, on ſome occaſions, at a great diſtance from the volcano.

When this matter is amaſſed in great quantity, and compreſſed by incumbent weight, it concretes into a ſpongy ſoft ſtone, called *tufa* by the Italians. And other parts of it, which remain in the ſtate of a ſort of gravel, are excellently adapted for forming ſtrong mortar with lime. They are brought from Italy for that purpoſe, and are called *puzzolana*. They are uſed for water buildings.

GENUS V.

FLEXIBLE STONES.

THE laſt ſection of the earthy bodies only now remains to be deſcribed,—that of the FLEXIBLE STONY BODIES. They are diſtinguiſhed by being flexible, or eaſily diviſible into parts which have great flexibility.

Theſe are concretions which are in general ſo ſoft as to be eaſily ſcraped or cut with a knife, and do not ſuffer any change of their hardneſs or ſtructure from the heat of a moderate fire, but in a ſtrong one many of them are eaſily melted.

Two of the claſſes formed by Cronſtedt, his *Micaceæ* and *Aſbeſtinæ*, are comprehended in this ſection of flexible earths. And it may with propriety be diſtinguiſhed into three ſub-ſections, the *plated*, the *fibrous*, and the *membranous* or *cellular* kinds.

The firſt of theſe ſubdiviſions, therefore,—the plated flexible ſtony bodies, contains the micaceæ of Cronſtedt, or the *talcky* foſſils of the Engliſh naturaliſts; ſo called from the principal ſpecies long known by the name of mica or talc.

It is a ſtone which feels unctuous and ſlippery between the fingers, and ſplits eaſily with a knife, like the foliaceous gypſum, into innumerable and exceſſive thin leaves, not only very flexible, but elaſtic;—employed for confining the objects in microſcopical obſervations. It is eaſily diſtinguiſhed from the foliaceous gypſum by its elaſticity, and by the effects of heat.

This ſtone is generally tranſparent in the thin plates, and often colourleſs. It is more commonly tinged, and ſometimes quite opaque. The colour is very various,—duſky, greeniſh, ſilvery, golden, and many other glittering appearances, which often deceive thoſe who are unacquainted with it. Theſe appearances do not proceed from metal, but from the diſpoſition of the plates.

Mica is found very plentiful in the compoſition of ſome kinds of rock, eſpecially ſome of thoſe which contain a large proportion of the fuſible earths;—in granite eſpecially, and in the ſchiſtuſes which contain garnets or granates.

But it is mixed beſides with ſome of the ſtrata which have been formed from the materials of demoliſhed rocks, as ſand, and ſandſtone, and gravel, and ſome clays.

The largeſt ſpecimens of tranſparent mica come from Ruſſia, where they have it in ſuch plenty and perfection, that in ſome parts of the country it is uſed for windows and lanthorns.

The flexibility of this foſſil explains the flexibility of a ſtone which was exhibited here in 1791, and is now in the cabinet of Lord Gardenſtone. It is about half an inch thick, and more than a foot ſquare. It is flexible to a moderate degree, but without elaſticity. It is compoſed of ſmall thin plates of mica, all parallel to one another, and intermixed with thin diſcontinuous plates of quartz. The great number and ſmallneſs of the plates, and the preſence of the quartz, prevent this ſtone from being elaſtic.

The ſecond diviſion of the flexible earths,—the fibrous,—comprehends foſſils which have the ſame chemical qualities with mica, and differ from it chiefly in their ſtructure, which is fibrous inſtead of being plated. There are many varieties of theſe, diverſified by the fineneſs and flexibility of the fibres, and by the cloſeneſs or looſeneſs of their connection. Thoſe reckoned the moſt curious and perfect, called amianthus, may be teaſed into a matter like cotton, which, being mixed with a ſmall quantity of flax, may be ſpun into yarn,

and wove into a cloth, which does not ſuffer from ordinary fire. The only uſe that has been made of this fibrous ſtone, is one for which modern cuſtoms do not find room. The ancients made a ſort of cloth of it, on which they laid dead bodies on the funeral pile, to preſerve the aſhes of the body by themſelves, and unmixed with thoſe of the fuel. Some have attempted to form it into paper; but it makes very bad paper.

The other foſſils which belong to this ſubdiviſion, are formed into membranes like leather, or elaſtic ſpongy maſſes like fleſh or cork. Theſe are named *mountain-leather*, *mountain-fleſh*, and *mountain-cork*, by the miners.

All theſe fibrous or membranous flexible ſtones are found in veins, or cavities of veins, and all contain the ſilica in largeſt quantity, but intimately combined with magneſia, alumina, lime, and a ſmall portion of iron. You will find the proportions ſtated in Mr. Kirwan's Mineralogy, and in Profeſſor Bergmann's Eſſays.

Magneſia is always a conſtituent part of the flexible ſtones, and is generally their moſt abundant ingredient after the ſilica.

APPENDIX.

PRECIOUS STONES.

AND now, gentlemen, I have taken ſome notice of the different kinds of earthy and ſtony bodies that appear to be moſt remarkably diſtinguiſhed from one another. Among all theſe, however, I have as yet made no mention of the PRECIOUS STONES, which may perhaps be thought a material omiſſion.

The reaſon is, that this title does not aſſemble together a ſet of ſtones that are ſimilar to one another by their nature or chemical qualities. It is a general name given to all ſtones remarkable for more or leſs tranſparency and brightneſs, or for ſome colour, or mixture of colours, or ſmoothneſs of ſurface, which has pleaſed the taſte of mankind. And the ſtones in which theſe qualities are found happen to be very different with reſpect to their nature and to the materials of which they are compoſed. I ſhall here give a ſhort enumeration of them.

I may begin by making a diviſion of them into STONES and GEMS. Under the firſt title I comprehend thoſe produced by nature in large maſſes, or in conſiderable quantity. Under the ſecond, thoſe which occur of ſmall ſizes only, and much more rarely, on which account they are far more coſtly than the others.

To the firſt diviſion belong,

1. Marbles.
2. Serpentines.

3. Alabaſters.
4. Some Porphyries.
5. Some Granites.
6. The Engliſh Pudding-ſtone.
7. Some Spars.
8. Some Jaſpers.
9. Some of the ſiliceous petrifactions of wood.
10. Some kinds of the Lapis Nephriticus.

1. *Of Marbles.*

The marbles are all limeſtones, or are compoſed of calcareous matter, and are different from the more common limeſtone only by agreeable colours, or mixtures of colours, and a more perfect compactneſs and greater hardneſs, which fits them for being more highly poliſhed.

Many marbles appear to have been formed from ſmall fragments of ſhells, ground down by agitation and attrition into ſand, which has afterwards been cemented by ſome natural operation. In many others we ſee diſtinctly the relics of the ſhells or lithophyta entire, or in large fragments. Marbles in which ſhells are ſeen in this manner are named by the Italians *Limacelli.*

When marbles are clouded or ſpotted with different colours, this is produced, either,

1*mo*, By theſe relics of ſhells and corals appearing in them; or more generally,

2*do*, By an unequal and irregular intermixture of iron, or inflammable matter through the ſtone, ſo as to form ſtreaks and ſpots which pleaſe the eye, by the contraſt of their colours, and the variety of their ſhades and diſtribution; or,

3*tio*, The variety of colours in ſome marbles have been formed by an operation they have undergone. We can plainly perceive that the ſtone has been fractured into a number of pieces, which have been ſet afloat

in a liquid marble paſte of a different colour, and are now cemented together by it.

Such marbles are named *Breccia* by the Italians.

All theſe have more or leſs beauty. But we may reckon among the moſt valued marbles, the pure white ſtatuary, and the perfect black. Such muſt naturally be rare. It cannot often happen that a block, of ſize ſufficient for a ſtatue or a groupe, is entirely free from ſpots or clouds, or ſtreaks of a different colour or tint.

2. *Of Serpentines.*

The moſt obvious diſtinction of ſerpentines from marbles is by their colour, in which a deep and duſky green prevails, and this is a colour but very rare in marbles. As to the nature of ſerpentines, ſome are partly calcareous, but all contain magneſia and iron. A ſpecies of porphyry is improperly called ſerpentine.

3. *Of the Alabaſters.*

This name is applied by the lapidaries to white ſtones that are ſofter than marbles, but capable of being well poliſhed. They are generally compoſed of the natural ſulphat of lime. But often calcareous ſtalactites and ſpars are alſo named alabaſters by the ſtone-cutters.

4. *Of the Porphyries.*

Of the porphyries there are only a few ſpecies reckoned precious or beautiful. One is dark green, with light green or white ſpots. Another is dark red or purpliſh, with whitiſh ſpots. And there are ſome the ground of which is almoſt black. They are harder than the marbles, but ſofter than the hard ſtones. I rank the porphyries among the fuſible ſtones, to which diviſion they certainly belong by

their properties and conſtituent ingredients. And many of our whinſtones, and many lavas in the volcanic countries, are coarſe porphyries.

5. *Of Granites.*

Some of the granites are alſo conſidered as ſtones of value. The nature of this ſtone was formerly deſcribed. The only certain ſpecies of it reckoned valuable are the Egyptian, the Ruſſian, and the Scotch.

6. *Of Pudding-Stone.*

Many pieces of the pudding-ſtone or gravel-ſtone found in England are alſo reckoned beautiful and precious.

7. *Of Spars.*

The ſpars reckoned precious or beautiful are ſome few calcareous ſpars, but chiefly *fluors* and *lapis Lazuli.* Fluors, admired for their beauty, are found plentifully in Derbyſhire. *Labrador-ſtone* is a feldt ſpar, or is nearly allied to it by its conſtituent parts. It derives its beauty from a certain diſpoſition of its tranſparent elements, which, like thoſe of pearl and mother of pearl, exhibit different lights as they are viewed in different directions. It frequently appears as if the ſurface was undulated, although it be perfectly flat. The opal has its beauty from the ſame cauſe. We ſee appearances of the ſame kind in ſome woods, ſuch as mahogany, ſatin-wood, &c. and in theſe the microſcope diſcovers the circumſtance on which it depends. We even ſee a little of it in ſome ſlates. When examined in their natural plates, they are really undulated; but when the ſurface is made flat and poliſhed, the undulated appearance is not entirely removed.

8. *Of Jaſpers.*

The name of jaſper is ſometimes applied to ſome marbles, but improperly. When uſed with propriety, it means hard ſtones, opaque and agreeably coloured by admixture of other matter with the ſiliceous, eſpecially iron. The moſt noted jaſpers that are beautiful are Sicilian, yellow, red, and white; green jaſper ſpotted red; Heliotropium.

9. *Of Siliceous Petrifactions of Wood.*

Some of the ſiliceous petrifactions of wood, when they happen to have the denſity of agate or jaſper, and are agreeably coloured, are alſo wrought by the lapidaries, as precious ſtones; and ſnuff boxes or other toys made of them.

10. *Of the Lapis Nephriticus.*

Laſtly, ſome kinds of the *lapis nephriticus* are in requeſt, on account of their agreeable colour, and the poliſh or ſmooth ſurface that can be given to them. The Turks, in particular, are fond of this ſtone to make the handles of their ſcimitars.

Having now ſaid enough of the firſt ſection of precious ſtones, thoſe, to wit, produced by nature in larger maſſes, we proceed to the ſecond; in which I include the gems, or thoſe produced in ſmaller maſſes, and more rarely.

The title of GEM was applied not long ago to a much greater number of ſtones than it is by late authors. I ſhall follow the old method, according to which the ſtones called GEMS were divided into SEMI-PELLUCID and PELLUCID GEMS.

1. *Semi-Pellucid Gems.*

The greater number of theſe belong to the order of hard ſtony ſubſtances, and are chiefly compoſed of the ſiliceous earth.

They are, in general, formed into ſmall maſſes in ſome kinds of rock, or fill up ſmall veins in it; or they are found among the gravel and earth into which ſuch rocks are reſolved, by the influence of time and the weather.

The ſiliceous matter, of which they are principally compoſed, has generally ſome degree of tranſparency; but this tranſparency is diminiſhed, and in ſome caſes a great degree of opacity induced, by the admixture of other matter. Often this diverſity of materials is ſo diſpoſed as to produce clouds, or ſpots, or ſtreaks of different colour and appearance, which add to the beauty of theſe ſtones.

Among the moſt notable kinds of theſe ſtones, we may reckon,

1*mo*, Agates.—Great numbers of them are found in ſome parts of this country, of a ſmall ſize, but ſome of them very pretty when poliſhed,—called *Scotch Pebbles*. I have already pointed out the origin of them. The internal arrangement of their matter is remarkable, and will be explained by Dr. Hutton, in a work he is now publiſhing on the formation of ſtones.

2*do*, Chalcedony, of the colour of the whey of milk. It is much eſteemed by ſeal-cutters, for a kind of *toughneſs*, as they term it, which makes it work without tearing up by their powders. This muſt ariſe from its having no grain or ſymmetrical arrangement of parts.

3*tio*, Carnelian, alſo valued by ſeal-cutters, as being very workable. The natural formation of carnelian is one of the moſt curious objects that mineralogy preſents to our eye. It has certainly been fluid as chalcedony, and the fluidity has been imperfect or clammy, and has been a very ſlow exudation from the rock or matrix to which it adheres. It is found hanging in tears from the ſides of the cavities, and theſe appear

to have hardened ſuperficially as it ſweated out; ſo that the long ſtring is all incruſted with little excreſcences, which have been, in ſucceſſion, the end of the drop. Theſe icicles often dip into a maſs of chalcedony, whoſe ſurface is perfectly ſmooth and flat, as if it had been fluid in a diſh, and the icicles can be traced through it, (it being in a ſmall degree tranſparent) to the bottom, without mixing with this maſs. The curious, and not inelegant form of the exudation, may be preciſely imitated, by putting a lump of hard pitch on a ſhelf, in warm weather. It will ſoften and drop down from the ſhelf in ſtrings, which are figured in the very ſame manner.

4*to*, Onyx, fit for cameos, by reaſon of its ſtrongly contraſted coats. Sardonyx is either a mixture of chalcedony and carnelian, or is a chalcedony ſpotted with ſmall red points.

5*to*, Mocoe, finely diverſified by tree-like figures, elegantly ramified.

6*to*, Opal, of varying colours like mother of pearl.

7*mo*, Turcoiſe.

2. *Pellucid Gems.*

Moſt of theſe alſo belong to the order of the hard ſtony ſubſtances, and ſome of them are the hardeſt ſubſtances produced by nature. A few belong to the fuſible claſs. They are always found in very ſmall maſſes, cryſtallized into regular figures, more or leſs peculiar to each kind; and when they are reckoned gems, have extraordinary tranſparency and brightneſs. They appear to be originally formed by nature in ſome kinds of rock, or in the veins of rock, and ſome are actually cut out of ſuch veins. But moſt of them are picked up from among gravel or earth formed by the decay of ſuch rocks which contain them.

The more common kinds of them, which bear but a moderate

price, are ſiliceous cryſtals, compoſed of the ſiliceous earth, with very little admixture of any other.

But thoſe which have the greateſt hardneſs and brilliancy, and which are named by the jewellers *true* or *oriental gems*, have been found leſs ſimple in their compoſition. A number of accurate analyſes of them, by Achard of Berlin, Profeſſor Bergmann, Mr. Kirwan, and others, have ſhewn that they contain the argillaceous earth in greateſt quantity, intimately combined with a ſmaller proportion of the ſiliceous, and a ſtill ſmaller of the calcareous, and of iron, to which metal they owe their beautiful colours. And it is only theſe tranſparent ſtones, which contain more of the argillaceous than of any other earth, which are diſtinguiſhed by the title of gems by Profeſſor Bergmann. I ſee no reaſon however for reſtricting the title ſo much.

We may here remark, that thoſe gems which contain a larger proportion of the argillaceous than of the ſiliceous earth, have not the ſame chemical qualities as the other hard ſtones in which the ſiliceous earth prevails above all others. They not only reſiſt the moſt violent heat without melting, when expoſed to it without addition, but it is extremely difficult to melt them by means of alkaline ſalts, which eaſily diſſolve the ſiliceous cryſtals into a glaſs. You may ſee, in Bergmann's Opuſcula, the other particulars by which they differ from the ſiliceous cryſtals. Some of the ſiliceous cryſtals are tinged, as well as thoſe reckoned true gems, with blue, or purple, or yellow, or other colours. But theſe are much rarer than the colourleſs cryſtal, and, when they have brightneſs, they paſs for gems; though, on account of their inferior hardneſs, they are not ſo highly valued, nor indeed have they ſo much brilliancy.

There are alſo ſiliceous cryſtals which have a duſky or brown colour, and yet have great tranſparency and brightneſs. Such are thoſe found in the mountains of Arran, and ſome other mountains of this country. And ſome of theſe brown cryſtals, by being heated equally

and cautiouſly, to a degree that is ſhort of ignition, loſe the brown colour, and retain a yellow one, which may be loſt alſo if the ſtone be heated too much. I knew a perſon who made profit by collecting theſe brown cryſtals, and converting them into yellow ones. Theſe convertible brown cryſtals are found in ſome mountains to the north-weſt of Aberdeen.

The pellucid gems may therefore be thus enumerated:

1*mo*, SILICEOUS CRYSTALS, colourleſs or coloured.

2*do*, The EMERALD, of a bright green colour, of which there are many varieties. It is much allied to ſchoerl; and ſome of the pale emeralds named *aqua marines* are true ſchoerls.

3*tio*, The TOURMALIN, though it be not a beautiful ſtone, being of a very duſky green, is however at preſent reckoned a gem. Its remarkable property is to be electrified by gentle heat alone, without being rubbed. It is alſo a ſchoerl.

4*to*, GARNATS that have tranſparency and brightneſs are uſed as gems. They have all of them a rich red colour, but differ very much in the deepneſs of this colour; when it is very deep the ſtone has leſs brightneſs. The very bright garnats in which the colour is leſs intenſe are named *ſcarlats*.

5*to*, The AMETHYST, of a bright and beautiful purple.

6*to*, The SAPPHIR, of a perfect and rich blue.

7*mo*, The TOPAZ, of a beautiful and brilliant yellow.

8*vo*, The RUBY, which has a red colour of great richneſs and brightneſs.

9*no*, The DIAMOND the moſt valuable of all. It is ſometimes ſlightly coloured, and even duſky and opaque; but the moſt colourleſs and brilliant are the moſt highly valued. The diamond is remarkable for four particulars:

1. It is one of the rareſt productions of nature. We are not certain that it is to be found any where except in the peninſula of India, and in the Brazils. In both places it is always found in detached ſo-

litary cryſtals, which are octaëdral, or often priſmatic, terminated by a pyramid. Theſe have ſometimes ſmaller cryſtals as it were growing out of them; but we have never met with the diamond in groups adhering to a ſhapeleſs baſe, as is the caſe in all other cryſtals. They have never been met with in the cavities of other ſtones; nor do we know any kind of rock or vein which may be ſaid to be the matrix of diamond. All that have been hitherto ſeen are found in looſe gravelly earth at no very great depth. This is waſhed and picked for the diamonds it may chance to contain. There are to be met with, in the cabinets of the curious, a very ſmall number of diamonds terminated at both ends with pyramids. This is, indeed, a very rare cryſtal of any kind. From the circumſtance of one end wanting a pyramid, we are entitled to ſuppoſe, that, like other cryſtals, they have originally adhered to ſome matrix. But, as has been ſaid, they have never been met with, except among what may be called the rubbiſh of ſome former condition of things. Several ſpecimens have been found wholly or partly incruſted with an opaque whitiſh matter of great hardneſs, but yet ſo ſoft as to have all its aſperities rounded by the attrition which the pebble has received. The jewellers call this mother of diamond, and, I think, with ſome propriety,—for in ſome that I have ſeen, the tranſition from diamond to this ſubſtance is not abrupt, but gradual, as in the caſe of the onyx. It was in the courſe of this century that diamonds were diſcovered in Brazil; and their price is now greatly fallen.

2. Diamond is no leſs eminently diſtinguiſhed by its extraordinary brilliancy and great refractive and diſperſive power,—far exceeding all other natural cryſtals. Mr. Zeiher, a German artiſt, has approached very near to the brilliancy, and to the refractive and diſperſive power of the diamond, in ſome of his compoſitions for imitating precious ſtones. But theſe fall infinitely ſhort of the diamond in its next remarkable property, viz.

3. Its ſuperior hardneſs. In this it exceeds all ſubſtances that are

known. It is therefore employed for ſawing and boring the hardeſt ſtones, and for engraving ſeals. For this purpoſe it is reduced to powder.

This powder is uſed in the ſame manner as ſand, emery, or other cutting powders, are employed by the lapidaries, viz. by moiſtening it with empyreumatic oil, and applying it to their wheel or drill; or the metal point uſed by the ſeal engravers, like a crayon. The metal employed for this purpoſe is the pureſt and ſofteſt iron. This takes faſt hold of the diamond powder,—it being preſſed into it by the force exerted in the operation: And the little particle never quits its place to roll about, but is carried along by the tool, acting like the tooth of a file, and tearing up whatever it touches. There is ſomething curious in the way in which diamond acts in cutting common glaſs. The glazier's diamond is by no means ſharp pointed. I have ſeen them as blunt and round and ſmooth as the head of a large pin; yet this, with a moderate preſſure, cauſes the plate to ſhiver under it wherever it is drawn. This is by no means a crack; but the glaſs being made ſomewhat weaker there, ſplits immediately, when gently patted on the other ſide with a hard body.

4. The diamond is ſtill more diſtinguiſhed from the reſt of the gems by its chemical properties, or the effects produced on it by heat and mixture with other bodies. The utmoſt violence of heat, even that of a burning mirror, does not induce the leaſt appearance of fuſion. Its aſperities are not perceptibly rounded, as has been obſerved in the ruby. The only effect of ſimple heat is, to diſſipate ſome foulneſſes which ſometimes taint its purity, or water, as it is called by the jewellers; but it makes no change in its texture, if the diamond has been free from previous cracks or flaws.

Nor does the utmoſt violence of ſimple heat volatilize the diamond. If it be protected from the action of the air, it ſuffers no diminution of its weight by the longeſt continuance in the fire. But if it be ſubjected to intenſe heat, and to a current of free air, it will

be entirely diſſipated, and this diſſipation is accompanied by the emiſſion of a dazzling white light. This was long thought to be a phoſphoreſcence, as in the caſe of many other cryſtals and ſpars; and the diſſipation was thought to be an exfoliation and diſperſion, like the decrepitation of ſalts. But if this were the caſe, the diſperſed duſt might be found. As this has never happened, chemiſts began to conclude that the emiſſion of light was an inflammation, and that the diamond was waſted by combuſtion like a piece of charcoal. The great rarity of diamonds, and the inability of moſt ſpeculative chemiſts to afford the expence of the neceſſary trials, has retarded the deciſion of this queſtion. But it is now paſt a doubt that the diamond is a pure inflammable ſubſtance. I ſhall therefore defer the conſideration of its combuſtion and its chemical relations till I come to the conſideration of that claſs of inflammables in which it muſt be placed.

Of the Corune, or Corundum.

After this notice of the gems, it may be proper to mention a ſingular foſſil, which, though not a gem, (for it is totally deſtitute of beauty) is yet allied to ſome of the gems by its conſtituent parts, and by ſome of its properties. This is the CORUNDUM, or, as it is called by the Britiſh lapidaries, the *adamantine ſpar*. The firſt ſpecimens of it came from China to Britain and it was afterwards found that it was to be got in India, not far from Bombay; and our naturaliſts have now found it in ſeveral granites of France and Spain. It is of a grey colour like emery. The entire pieces are opaque, but very thin plates of it have conſiderable tranſparency. What comes from China has very evident hexagonal cryſtals; but all other ſpecimens that I have ſeen are of an indeterminate granulated ſtructure. What comes from Bombay is more unlike to emery, and conſiderably whiter than all others; and it is this which is called corundum by the natives.

The remarkable quality of corundum, and for which it is chiefly valued, is its extreme hardneſs. It ſcratches every ſubſtance but diamond; and is therefore of great value to the lapidaries and ſeal engravers of this country, who employ it by the name of adamantine ſpar. It is but a little harder than the ruby, the ſapphir, or the oriental topaz. It is far ſuperior to emery, particularly for grinding on the wheel, to which it adheres like diamond duſt. One part of it does as much work as four of emery, and does it in half the time.

The corundum unites with cauſtic ſoda, but with great difficulty. When the liquor ſilicum formed with it is decompoſed by acids, it is found to conſiſt of one-third of a peculiar earth, and two-thirds of clay.

Many of the precious ſtones are imitated by art. The marbles, and porphyries, and jaſpers, by means of paſtes compoſed of lime and gypſum, with other materials added to increaſe the hardneſs and ſmoothneſs, or to give the colours. The art of making theſe imitations has been carried to a great degree of perfection. Large columns, pilaſters, pannels, tables, mouldings, feſtoons, and other embelliſhments of the inſide of buildings, have been executed very like to the more beautiful and coſtly kinds of marble and porphyry. And theſe imitations have the advantage of being procured at very little expence compared with the originals. But they are only fit for the inſide of houſes: The materials do not withſtand the weather.

The pellucid gems are imitated with glaſs, made with great care and in ſmall quantities for this purpoſe alone; the very pureſt materials being employed, and certain additions being made to improve the tranſparency and brightneſs of it, ſuch as borax, and ſome of the metallic ſubſtances; ſome of which alſo give to the glaſs the different colours of the gems. The moſt celebrated authors who have written on this art are Neri, Merret, and Kunkel, whoſe works appeared firſt in the German language, but have been collected together and tranſ-

lated into French, with the title of *Art de la Verrerie*,—the art of glaſs-making.

Theſe artificial gems, or paſtes as they are called by our jewellers, are very good imitations in ſome reſpects, and repreſent the beauty and brightneſs of the natural productions very nearly, but they cannot be compared with them in hardneſs and durability.

Setting aſide, however, the attempt to imitate the natural gems, we may venture to ſay that art has in ſome reſpects far excelled nature in the productions it has obtained by working on the earthy ſubſtances. We have examples of this in the manufacture of the common kinds of glaſs, and in that of porcelain, and of the other beautiful and uſeful kinds of pottery.

The common kinds of glaſs muſt no doubt be allowed to be far inferior in brightneſs, as well as in hardneſs and durability, to ſome of the tranſparent ſtony bodies produced by nature. But the inferior hardneſs of glaſs is a great advantage in ſome reſpects, by rendering it more eaſily cut, engraved, and poliſhed, and thereby making it a fitter ſubject for manufactures. And the facility with which we can procure large maſſes and quantities of it, and the ſoftneſs and ductility which it receives from heat, in conſequence of which it is ſo eaſily formed into any ſhapes we deſire, render it a moſt uſeful production, and raiſe its intrinſic value far above that of the gems, which are produced by nature in ſuch very ſmall quantities, and are ſo difficultly wrought into any form, that they are rarely applied to any other purpoſe than the gratification of weak-minded vanity.

Of Porcelain.

Porcelain is another production of art which has been invented upon principle, by making chemical experiments upon the earthy and ſtony ſubſtances, and which deſerves to be admired for the elegance and uſefulneſs of its productions.

The art of making porcelain was long confined to the eaſtern parts of Aſia. It is now underſtood and practiſed in ſeveral parts of Europe, eſpecially Dreſden, Paris, and ſome other places in France, and in ſeveral towns in England. It is a branch of the art of pottery, brought to an extraordinary degree of perfection, ſo as to produce veſſels and other pieces of work, not only very elegant, and capable of high decoration, but which have the qualities the moſt deſirable in veſſels of earthen ware intended for the purpoſes of common life. The qualities I mean are, 1*ſt*, Great compactneſs of texture, by which it is both ſtronger, and made impenetrable and untainted by any thing put into it; whereas all the ſoft pottery is comparatively much weaker, and is moreover bibulous, and indelibly impregnated with almoſt every thing that we put into it; 2*dly*, A ſmoothneſs of ſurface which gives the veſſels beauty, and makes them eaſily cleaned; 3*dly*, A texture which allows conſiderable alterations of heat and cold ſuddenly applied without cracking, as glaſs does.

We cannot tell by what ſteps this art aroſe to perfection ſo early in China and Japan, from whence the art was imported into Europe about fifty years ago. Du Halde has given a faithful account of the Chineſe manner, as far as he underſtood it; but unluckily Du Halde was but a ſorry chemiſt.

Perhaps the circumſtance which gave origin to it in thoſe countries was the abundance of proper materials, which are but rarely found in Europe. The materials of which the beſt kinds of procelain are compoſed are two: The firſt is a clay of the beſt and whiteſt kind, called by the Chineſe *kaolin*; the other is a ſtone, which they are under a neceſſity of reducing to a fine powder, to prepare it for mixing with the clay in different proportions. This they call *petuntſé*. This ſtone is no other than either pure feldt ſpar, or, in want of it, a ſpecies of granite abounding with feldt ſpar, and quite free from any admixture of iron, or other dark coloured matter, which might ſpoil the whiteneſs of the porcelain. The effect of this ſtone, when added

in moderate quantity to the clay, is to make it aſſume the greater degree of compactneſs in a moderate fire, and to give it ſemitranſparency, without communicating too great a degree of fuſibility. The Chineſe call it the *fleſh*, and the clay the *bones*. A granite, quite free from iron or other colouring matter, is r[illegible] urope; but there are places where ſuch are found, particularly in Cornwall, where there is a great variety of granite called *moor-ſtone*. And a company ſome time ago obtained a patent for the eſtabliſhment of a porcelain manufactory of the beſt quality, in England, with intention to uſe that Corniſh moor-ſtone.

Though theſe two ingredients are in general the conſtituent parts of the beſt porcelain, it has not been always neceſſary to mix them artificially together. It has happened both in China and in England that nature has in ſome places performed this part of the work, or furniſhed materials which do not need admixture. In ſome parts of Cornwall, where the granite or moor-ſtone abounds, they find a white clay mixed with the ſandy rubbiſh of the moor-ſtone in ſuch proportions that, without any other trouble than that of ſeparating it by water from the coarſer particles, it makes excellent porcelain.

A conſiderable maſs of Chineſe porcelain clay was brought to this country ſome time ago, and worked up by our beſt artiſts. It makes perfect porcelain, but of that kind called *ſtone china*, viz. leſs tranſparent than common. To give it the degree of ſemitranſparency expected in common porcelain, it is neceſſary to add ſome of the *petuntſé*. But it may alſo be uſed alone, and then forms *ſtone china*, or *Nankeen china*. This kind of clay is manifeſtly produced by the gradual decay of the granite into rubbiſh and powder, during which decay it appears to loſe ſome degree of its fuſibility. We have proof of its origin by microſcopic examination, by which we find in it the mica and quartz, and other materials of the granite. Magneſia, or the earthy bodies which contain it, are alſo excellent ingredients in the compoſition of porcelain. There is ſome of it contained in feldt ſpar and the granite, &c. Some of the porcelain manufactories in England employ

the *ſoap-ſtone*, or *ſteatites*, in their compoſitions with good effect. The good qualities of this earth, are, 1*ſt*, To increaſe or improve the whiteneſs of the porcelain; 2*dly*, To preſerve it from ſoftening too much, or melting by heat.

The clay being worked into the intended form, is dried in the air, and then put into the kiln, and baked with a moderate heat, and for a ſhort time. This brings it into the ſtate of our ſoft potteries. It is then glazed and painted. The glazing is made by dipping it into a cream of powdered flint, with the addition of a little borax or barilla and other colourleſs materials, to make it take a thin fuſion. Before dipping the piece, the blue colours have commonly been put on, becauſe this colour is too apt to diffuſe or run. The other colours are penciled on after it has been dipped. Many of the more ordinary European porcelains are covered with an opaque white varniſh or enamel; but this is to cover ill-coloured clay, and may be known by its thickneſs and ſoftneſs. The fine porcelain glaze is perfectly tranſparent, and as thin as a film of water. The piece is now baked again with a much greater heat, and for a much longer time; the particles now take a new coheſion and arrangement; and the piece becomes hard and compact, breaking with a dull luſtre and ſomewhat of a granulous texture: But in the very fineſt porcelain no grain can be perceived, even with a microſcope; and the fracture has ſcarcely any luſtre, and reſembles the fracture of white wax.

Theſe are, therefore, the materials of the beſt kind of porcelain. But that we may not leave any part of this ſubject untouched, it is neceſſary to mention, that very near imitations of this kind of pottery may be made with materials different from theſe; and many of the manufactories which have been eſtabliſhed in Europe make uſe of thoſe other materials, and produce only imitations of porcelain. They muſt all employ a fine and white clay for one ingredient in the compoſition. In this they neceſſarily agree: But they have gone different ways in ſearch of their fuſible ingredient, which gives to the clay the proper degree of compactneſs and ſemitranſ-

parency. As a granite or feldt ſpar ſufficiently free from irony particles occurs only in very few places of Europe, they have endeavoured to ſupply its place by other ſubſtances. Some have employed different kinds of gypſum, which, being fuſible in a violent heat, anſwers in ſome meaſure the purpoſe of feldt ſpar. Others employ ſome of the alkaline earths, which, though not fuſible themſelves, produce fuſible mixtures with clay and flinty earth. But greater numbers have had recourſe to the ingredients of glaſs made into what is called frit, ground to a fine powder. The quantity of alkali in this compoſition is not ſufficient to make it melt into a tranſparent and fluid glaſs, but makes it approach a little to that ſtate, or makes it ſemitranſparent. But theſe imitations are not porcelains. They are glaſſes or enamels not completely vitrified; and a greater heat will melt them. Even in inferior heats they go out of ſhape in the kiln by their own weight. Such ware cracks by any ſudden change of heat. It is alſo ſoft externally, and ſoon ſcratched and ſullied, becauſe the ware will not ſtand the heat neceſſary for fuſing a hard varniſh. Mr. Reaumur, of the French Academy, who firſt examined the Chineſe materials, was alſo the firſt who ſuggeſted this ſubſtitute of frit in place of petuntſé where it could not be procured; and upon the ſame principle he attempted to change common glaſs into porcelain. He was led into this project alſo by accidental experience, as has been already mentioned.

Another author, in purſuit of the ſame object, ſometime ago was induced to make a very great number of experiments, which have proved a conſiderable addition to our knowledge on the ſubject of earths. The author I now mean is the late Mr. Pott of Berlin, who publiſhed theſe experiments in two ſmall volumes, with the title of *Lithogeognoſia*. But the nature of many of the earths and ſtones was not ſo well underſtood at that time as it is now; and he conſidered many compounded ſubſtances as ſimple earths. His experiments, however, excited a curioſity in other chemiſts to examine ſome of the purer earthy bodies in this manner.

And there have ſince appeared, in the *Memoirs of Berlin*, papers, containing experiments of this kind, by Mr. Margraaf, and by Mr. Achard: And a multitude of experiments have been made in France, by Monſ. d'Arcet, and by ſeveral others. Such experiments are intereſting, as having a tendency to improve or illuſtrate the arts of pottery, glaſs-making, and metallurgy.

But no perſon has made, perhaps, ſo many experiments on the mixture of different earths for the compoſition of earthen ware and porcelain as Mr. Wedgewood. His object was to diſcover paſtes, or compoſitions, which ſhould have, not only the denſity and hardneſs of porcelain, but different colours; and he has ſucceeded in finding ſome of very agreeable colours,—ſuch as what he calls his artificial jaſpers, with which he executes beautiful pieces of workmanſhip, with figures in baſſo relievo, of the fineſt white porcelain, on a coloured ground. In this way he has imitated a famous vaſe, that is reckoned one of the moſt extraordinary examples of the excellence of ancient workmanſhip,—the Barbarini vaſe, now in the poſſeſſion of the Duke of Portland. Mr. Wedgewood viewed this piece of antique pottery with the higheſt admiration, declaring that the artiſt deſerved a thouſand guineas for his work. The work in relievo is executed with the moſt perfect ſharpneſs and preciſion, and is an enamel altogether opaque; ſo that where it is not ſo thick as the fineſt poſt paper, the colour of the ground does not appear through it,—an excellence which all his labours had not yet attained.

The true porcelains are now made in ſeveral parts of Europe in great perfection,—equalling the Aſiatic in the beauty of the material, and even exceeding it in its moſt valuable qualities, of ſtrength and its ability to withſtand great and ſudden heats without ſplitting or ſoftening, and going out of ſhape. Saxony produced the firſt of ſuperior quality, but it is now excelled by the porcelain of Seve in France. The manufacture is daily extending, by the diſcovery of more copious materials; but ſtill, the Oriental is far cheaper than any European porcelain of equal goodneſs.

APPENDIX.

OBSERVATIONS BY DOLOMIEU ON QUARTZ AND PRECIOUS STONES.

(Obſerv. de Phyſ. May 1792.*)*

1. QUARTZ, or cryſtal, phoſphoreſces when heated or ſtruck.

2. It alſo, when ſtruck, emits a peculiar odour. Theſe phenomena indicate inflammable matter.

3. It decrepitates when ſuddenly heated, and the more phoſphoreſcent it is it decrepitates the more.

4. It boils and bubbles very much when melted with the heat of vital air acting on charcoal; and is formed into globules, white or opaque, with air bubbles.

5. When melted with fixed alkalis, there is a great effervescence or boiling, although the alkali be cauſtic. (The author has alſo obſerved a flame come from this mixture; and ſo has alſo Mr. Pelletier.)

6. If there be enough of the fixed alkali, the compound diſſolves in water and forms the liquor ſilicum, which contains the ſiliceous earth, certainly different from what it was before. For, if we precipitate it with an acid, and inſtantly add ſuperfluous acid, it is rediſſolved by that acid.

7. The author had long ſuſpected that quartz contained ſome condenſed gas or elaſtic aëreal matter, and he at laſt made ſome experiments along with Mr. Pelletier. They put into an earthen retort of

twelve cubic inches capacity, ten drachms of levigated quartz, and two ounces of cauſtic potaſh, freſh made and quite dry, and ſet the retort in a reverberatory furnace, with a receiver and apparatus for elaſtic fluids, which were confined in this proceſs by water. 1*ſt*, There came ſome air, which he expected to be atmoſpherical air, from the cavity of the retort, but after two or three cubical inches were come, all the reſt extinguiſhed flame, and appeared to be azote, to the quantity of 22 cubic inches. 2*d*, A little ceſſation happened in the emiſſion of elaſtic matter, and a tendency appeared to the abſorption or intropulſion of the water. The fire was therefore increaſed; and ſoon after, that is, when the bottom of the retort began to be red, an elaſtic fluid was again emitted, along with a good quantity of white watery vapours, and a white ſmoke that, while it riſes in bubbles through the water, is not totally diſſolved or combined with it. This white ſmoke diſappears after it has riſen out of the water into the bell. During this ſecond production of elaſtic matter, 12 cubic inches of it are obtained; and there is a limit here too, marked by a ceſſation, attended with ſtill greater danger of intropulſion of the water than in the firſt inſtance. It muſt be avoided, either by letting in ſome air, or by increaſing the intenſity of the fire with bellows. The nature of this ſecond product is different from that of the former: It is all inflammable air which explodes with atmoſpherical air, excepting a ſmall portion of it which is mixed with air and gas azote. 3*d*, The third product, which requires a very ſtrong heat to make it come, amounts to 20 or 22 cubic inches: About 16 of theſe are fixed air, which is gradually abſorbed by the water,—the remaining five or ſix are a mixture of inflammable and azotic gas, in which the laſt prevails. After this, whatever heat be applied, no more elaſtic matter can be obtained. (The author obſerved ſigns as if ſome of this matter were attracted and abſorbed by the water.) They repeated this experiment with levigated cryſtal of Madagaſcar, and cauſtic fixed alkali, which was prepared by Mr. Pelletier, with all precautions to have it pure

and untainted with inflammable matter. And the proceſs was twice performed with this cryſtal: The firſt time the heat was not raiſed ſo high as to bring over the third product of gaſes, but the ſecond was completed. The reſiduum in the retorts, after the firſt and laſt experiment, was a white, vitrified, opaque, blown-up matter; that of the ſecond experiment was perfectly vitrified, and proved a greeniſh glaſs. But all theſe three were very diſſolvable and even deliqueſcent; and were diſſolved by water into a liquor ſilicum, which by reſt depoſited a fuliginous-like matter.

8. The author is of opinion that the inflammable and azotic gas come from the quartz, for theſe reaſons: 1*ſt*, The alkali is not decompounded or deſtroyed, but can be ſeparated again entire from the ſilica by acids. But the quartz is certainly very much changed, for it is become ſoluble in all the acids, even the acetous, provided theſe are added in a ſufficient quantity as ſoon as it is precipitated from the liquor ſilicum. The ſulphuric acid ſometimes rediſſolves it ſo quickly that the precipitation or ſeparation of it from the alkali is not perceptible; and the ſame thing happens with any other acid, if the ſolution of the liquor ſilicum be largely diluted. That there is a real ſolution here by the acid, becomes evident when we add enough of alkali to ſaturate the acid, for then the ſiliceous earth is precipitated again, eſpecially when the alkali we uſe is a mild alkali, and moſt certainly if the volatile alkali. For if we uſe a cauſtic alkali, it is neceſſary to take care that no more be added than juſt enough. A little ſuperfluity of it rediſſolves the ſilica very quickly again; and thus it can be rediſſolved by acid or alkali as often as we pleaſe.

The author believes that the inflammable and phlogiſticated airs come from the quartz; and that the boiling and blowing of it up into a ſpongy glaſs, when it is melted by the heat of vital air, is occaſioned by the extrication of thoſe airs from it; that the fire or light, and the ſmell of burnt air, produced by ſtriking pieces of quartz againſt one another, are to be imputed to the baſes of thoſe airs in its compo-

ſition; and that the difference between quartz in its natural ſtate, and quartz freſh precipitated from liquor ſilicum, is ſomewhat analogous to that of quicklime and calcareous earth; the freſh precipitated ſilica, in conſequence of its purity and ſimplicity, having an attraction for acids, which quartz has not. And as the quicklime recovers its fixed air, if left expoſed, the author is of opinion that the precipitated ſilica can recover from water the principles which it loſt when it was melted with the alkali; for the precipitated ſilica continues ſoluble in acids for a very ſhort time only after it is precipitated. If we obſerve it while we are precipitating it, we can ſee intermixed with it, and forming around the particles of it, numerous little bubbles of aëreal matter, which riſe afterwards to the top of the water. And heat promotes and increaſes this appearance, which is ſoon over, and then the ſilica is inſoluble in acids, as much as quartz in its natural ſtate. And if we now waſh and dry it, and melt it again with an alkali, it gives the ſame effervеſcence that it gave at the firſt. It muſt be acknowledged that inflammable air is not abſorbed by newly precipitated ſilica; but the author ſuppoſes that it is only the baſis of it which is preſent in quartz; and that baſis, when once combined with caloric, is not very eaſily ſeparated from it.

If theſe airs are ſuppoſed to come from the alkali, how can we account for the effervеſcence or intumeſcence of pure quartz and cryſtal when melted with the heat of vital air, or for the light and the ſmell of burnt matter, which are produced by ſtriking pieces of quartz againſt one another? The Chevalier de Lemanon, performing this experiment over white paper, and examining afterwards with a microſcope the minute duſt or particles which had been rubbed off from the quartz, found among them, particles which had been ſcorified, and which, when rubbed or bruiſed on the paper, marked it like charcoal. (*Journ. de Phyſ.* July 1785.)

The matter we find thus combined with the ſilica in quartz is probably the matter which, when combined with water at a great depth be-

low the ſurface of the earth, enables it to diſſolve quartz, and to tranſport it and to cryſtallize it, which matter cannot probably remain combined with water when it comes to the ſurface and is expoſed to light. Bergmann was deceived when he imagined fixed air combined with water to be a ſolvent of quartz: The experiments of other chemiſts have not ſupported this opinion. I have not been able to make it diſſolve ſilica, even when freſh precipitated from liquor ſilicum. Siliceous cryſtals are often formed in nature on the ſurface of calcareous ones, without the ſmalleſt appearance of diſſolution or corroſion in theſe laſt, which would certainly happen were the ſolvent of the ſiliceous matter *carbonic acid water*. Mr. Morveau alſo miſtakes this water. (*Encyclopedie Methodique*). For, in an experiment in which ſiliceous cryſtals were formed by ſhutting up in a veſſel aërated water and ſiliceous earth, there was iron alſo, which became corroded and ruſted, and the cryſtals were found among the ruſt of the iron. He had four glaſſes, containing aërated water and ſilex. Into one was put ſilex; into another limeſtone; into a third, argilla; and into the fourth, iron. After nine months, no change appeared, except in the laſt, in which both the pieces of quartz and the iron were evidently corroded, and ſmall cryſtals found among the ruſt of the iron. Dolomieu therefore concludes that the hydrogen, ſeparated by the action of the diſſolving iron on a ſmall part of the water, produced, in conjunction with the reſt of the water, a ſolvent which acted on the quartz. Dolomieu learned, however, by experiments, that iron has no effect on the liquor ſilicum, or the liquor on the iron. A bit of poliſhed iron preſerves its brightneſs unimpaired in this fluid. That the ſolvent of ſilica in nature is an inflammable ſubſtance, is alſo rendered probable by the duſky colour of ſome cryſtals and of flint, which dark or duſky appearance is diſſipated by fire. He adds one more argument to ſupport his opinion of the compounded nature of quartz and cryſtal. This is drawn from its inactivity, or want of attraction for moſt other ſubſtances.

He then enters on the conſideration of the gems, which have ſtill more inactivity, and are inſoluble even by alkali, though they are penetrable by it to a certain degree. He appears inclined to ſuppoſe that theſe are ſtill more completely ſaturated than quartz, with the matter which he has diſcovered in its compoſition. And ſome of the properties of the diamond may give room for ſuppoſing that it is the moſt completely ſaturated of them all, and therefore the moſt difficultly penetrable and diſſolvable by the moſt active ſolvents.

He conſiders the argil, which is the moſt abundant ingredient in many of the gems, as diſſolvable by the ſame ſolvent which is neceſſary to quartz. The argillaceous earth ſhews, by its odour when moiſtened, and by many other particulars, that it has a diſpoſition to unite with inflammable matter.

He afterwards conſiders the different gems, as differing not only by the number and proportion of earths they contain, but alſo by the cloſe coalition of thoſe earths, which has been produced by the action of their common ſolvent,—and ſuppoſes that the hardeſt and brighteſt of them retain a larger proportion of the remainder of this common ſolvent, or are more completely ſaturated with it, than the reſt are.

But I refer you to the concluſion of his paper, which, I confeſs, is not ſo clear and diſtinct in the preceding parts.

CLASS III.

INFLAMMABLE SUBSTANCES.

THE third claſs of the objects of chemiſtry, in the plan which I have adopted, is that of the INFLAMMABLE or COMBUSTIBLE SUBSTANCES.

By the *inflammation* of a body, is meant a rapid deſtruction and change, which it ſuffers when expoſed to the action of heat and air at the ſame time; which change is attended with the emiſſion of a great quantity of heat and light, and ends in a total loſs or privation of the quality of inflammability.

When the general effects of heat were formerly explained to you, ſome notice was taken of the phenomena of inflammation, and of the general nature of this claſs of bodies. And the opinions which formerly prevailed, as well as thoſe which now prevail concerning the nature of it, were briefly ſtated, and have ſince been more fully explained to you occaſionally.

The opinion that is now the moſt generally approved, had its riſe from the numerous inveſtigations and experiments that have been made ſince the laſt twenty or thirty years on the nature and properties of the different elaſtic fluids which are found in nature, or may be produced by art.

After I had diſcovered the particular nature of the carbonic acid, and had ſhewn that ſome of it is produced by the action of air and burning fuel on one another, and alſo by the breathing of animals, I ſuppoſed that it was formed by the union of common air, with a quantity of the phlogiſton of the chemiſts, the exiſtence of which was not doubted at that time. And I ſuppoſed that atmoſpherical air had a ſtrong tendency to unite with this principle, and to ſeparate it on many occaſions from other bodies.

This opinion of a tendency in the atmoſpherical air to unite itſelf with the ſuppoſed phlogiſton, was afterwards adopted by Dr. Prieſtley and others. But the Doctor did not admit the carbonic acid or fixed air to be produced in the manner I had ſuppoſed. He examined with more care than I had done the change which the air undergoes in contributing to the inflammation of burning bodies and the breathing of animals, and thus diſcovered the diſtinction between carbonic acid gas and azotic gas. This diſtinction had been in fact clearly pointed out before, by my colleague Dr. Rutherford, in his inaugural diſſertation, printed in June 1772.

When atmoſpheric air is completely vitiated by the breathing of animals, or the burning of fuel, we find in ſuch vitiated air a much greater quantity of the azotic gas than of the carbonic. Dr. Prieſtley was of opinion that the azotic gas was formed by the combination of the atmoſpherical air with the phlogiſton; he therefore named the the azotic gas *phlogiſticated* air. The carbonic acid gas, he ſuppoſed, had exiſted before, but was concealed in the atmoſpherical air, or was intimately combined with it until phlogiſton was added, which, uniting with the air, made it ſeparate from the carbonic acid gas. Or, as he expreſſed it, the carbonic gas, or fixed air, was precipitated, or extricated, in conſequence of the phlogiſtication of the atmoſpherical air.

So far had Dr. Prieſtley proceeded, when the late Dr. Crawford of London employed his attention upon this ſubject. By taking hold of the diſcoveries of others, and making uſe too of experiments made

by himſelf, he formed a new theory of inflammation, which he publiſhed in his work on Animal Heat.

He made a number of experiments to learn what capacity for heat different ſubſtances have when compared with one another. Theſe experiments were made in the manner which I pointed out, by applying different bodies one to another unequally heated. A part of the heat of one is communicated to the other, until they come to an equilibrium or equal temperature of heat. While this happens, the alteration of temperature in the one body is very different from that of the other, although the heat which the one receives be preciſely the ſame quantity which the other loſes.

This ſhews, therefore, that different kinds of matter have different capacities for heat; that ſome are more heated by the ſame quantity of heat than others, or that a ſmaller quantity of the matter of heat is ſufficient for raiſing their temperature or thermometrical heat by the ſame number of degrees, (for this is the mark and the only meaſure of capacity).

Dr. Crawford, making a great number of experiments in this way, with different materials, thought that he diſcovered that thoſe which he ſuppoſed to contain the phlogiſton in their compoſition had leſs capacity for heat than others, or required leſs of the matter of heat to raiſe their temperature, and that in proportion as they contained the more of the imaginary phlogiſton, they had the leſs capacity for heat.

He therefore began to think that atmoſpherical air, while it received this phlogiſton from burning fuel, muſt have its capacity for heat diminiſhed, and muſt throw ſome of its heat into the contiguous bodies; and that the increaſe of heat which appears during inflammation, might be this very heat extricated and expelled from the air, and not from the burning body.

This led him to examine, by actual experiments, the capacity for heat of the air in its different ſtates. And he thought that he diſcovered ſuch a very great difference between the capacity of atmoſpherical

or reſpirable air, and that of the azotic and carbonic gaſes, that he was able to ſhew by calculations that this is ſufficient to account for all the heat that appears during the inflammation of fuel.

Theſe are the general outlines of his theory of inflammation, which he has applied alſo to explain the heat maintained in the bodies of animals. For particulars I muſt refer you to the firſt and ſecond editions of his treatiſe on this ſubject, which contains experiments made with amazing labour and much ingenuity.

While Dr. Crawford was thus employed, another perſon in a diſtant part of the world, had already formed for himſelf a very different theory of inflammation. This perſon was the late Mr. Scheele of Sweden, whom I have had frequent occaſion to mention already in this courſe, as an eminent chemiſt and philoſopher.

He engaged himſelf in an inquiry which had for its object the nature of inflammation, and how heat and light are produced by it: And he thought that he had diſcovered how they are produced. He thought that he had reaſon to conclude that heat and light are compounded ſubſtances, and that he could actually produce them, by combining together their conſtituent ingredients; and that he could decompound them, by ſeparating theſe ingredients from one another.

Aſſiduouſly occupied in this reſearch, he was one of the firſt diſcoverers of vital air, or oxygen gas. Dr. Prieſtley alſo diſcovered it about the ſame time, having obtained it from nitric acid, and from other things, in ſome of his numerous experiments. Mr. Lavoiſier alſo diſcovered it ſoon after, while he was employed in inveſtigating the action of air on the metals.

But Scheele was the firſt perſon who, from a number of ingeniouſly contrived experiments, concluded by very fair reaſoning, that atmoſpherical air is a mixed fluid, compoſed of about two parts of azotic gas, and one part of vital air or oxygen gas, along with a very ſmall admixture of carbonic acid. The greater part of the carbonic acid gas

found in the air which has contributed to the burning of fuel, he ſuppoſed to be extricated from the fuel, moſt kinds of which he ſuppoſed contained this acid, or the baſis of it. But he obſerved that there are ſome inflammable ſubſtances which do not contain any of this baſis, and therefore do not communicate carbonic acid to the air which contributes to their inflammation. Such are ſulphur, phoſphorus, and ſome of the metallic ſubſtances.

Scheele, after making many experiments with atmoſpherical air, repeated them alſo with the oxygen gas, by burning ſome of the moſt inflammable ſubſtances in limited quantities of it, which he had confined in cloſe veſſels; and he found that in ſome of theſe experiments the *whole* of it was expended, or diſappeared during the bright and violent inflammation which it occaſioned. This he learned by opening the phials under water, after the experiment. The water was puſhed in by the preſſure of the atmoſphere, and filled them quite full. He therefore concluded that the oxygen gas had penetrated through the glaſs of the phial, and had eſcaped in the forms of heat and light, into which forms it had been changed by uniting with the phlogiſton of the inflammable matter. The heat, he ſuppoſed, was produced by a leſſer, and the light by a greater proportion of the phlogiſton combined with it.

We muſt not form a light opinion of Scheele's acuteneſs and judgment from the extravagance, and I may almoſt call it abſurdity, of ſuch a theory, as it appears to us at preſent. Scheele was one of the moſt judicious, as well as ingenious chemiſts that ever lived; but in the active time of his life, the exiſtence of phlogiſton was univerſally believed. It was ſo firmly eſtabliſhed in the imagination of every chemiſt, that it preſented itſelf to their minds on every occaſion. It muſt be confeſſed, however, that he may be blamed for a groſs overſight or neglect, in omitting to weigh the phial and its contents before and after the inflammation. Had he weighed it accurately, he would have learned that the oxygen gas had not flown away through the

ſides of the phial, but was ſtill there, having only loſt its elaſtic aëreal form. Had he examined the weight of the acid into which the inflammable body was changed, he would have found that this acid matter contained the oxygen in a condenſed ſtate; the weight of it being equal to that of the inflammable body and of the oxygen gas taken together.

When he performed the ſame experiment with atmoſpherical air, no more than one-third or one-fourth of it was expended, or had diſappeared. The remainder was become totally unfit to contribute to the inflammation of burning bodies, or to ſupport the life of animals by reſpiration. And when he examined it further, he found it to be either pure mephitic gas, in ſome caſes, or a mixture of this gas with carbonic acid gas in others. He then, by the uſe of lime and water, ſeparated the carbonic acid gas when it was preſent, and he added to the mephitic gas as much pure oxygen as made up the whole to the original quantity of the atmoſpherical air with which he had begun the experiment. He found this mixture to be exactly ſimilar, in its powers and properties, to good atmoſpherical air. He exhauſted it of its oxygen, by burning bodies in the ſame manner as before. And he again renewed its powers in the ſame way ſeveral times over; and, as the quantity of the azotic gas always continued the ſame, he concluded that atmoſpherical air is effectual in promoting inflammation and ſupporting the life of animals, only in conſequence of its containing near a third part of its bulk of oxygen gas in its compoſition; and that it is only this part of the atmoſpherical air that is capable of uniting with the phlogiſton, and of being converted along with it into heat and light.

The moſt ſurpriſing and ingenious part of his treatiſe was the apparent facility with which he thought he could explain the various proceſſes by which oxygen gas could be obtained in its ſeparate ſtate. They are all proceſſes in which ſubſtances, which were ſuppoſed by the chemiſts to have a ſtrong attraction for the phlogiſton, were expoſed to the action of heat. And he ſuppoſed that they decom-

pounded the heat applied to them,—that they attracted the phlogiſton, and diſengaged the oxygen from it. And no perſon diſcovered ſo many ways to obtain the oxygen gas in a ſeparate ſtate, or to extract it from ſo many different ſubſtances, as Mr. Scheele did.

You muſt perceive that all the attempts to explain combuſtion that have been mentioned, agree in ſuppoſing or aſſuming the exiſtence of a common or general principle of inflammability contained in all inflammable ſubſtances. It is further ſuppoſed that this is a moſt ſubtile kind of matter, and that it is ſeparated from ſuch bodies with great rapidity during their inflammation, appearing then in its ſeparated ſtate, according to the firſt opinion of the chemiſts, in the form of heat and light; or, according to the opinion which I had formed, and to that of Prieſtley, Cavendiſh, Crawford, Kirwan, and others, uniting, at leaſt in part, with common air, and forming carbonic acid and azotic gas; or, thirdly, according to Scheele, uniting itſelf with the vital air of the atmoſphere, and forming with it the heat and the light.

I muſt now make you acquainted with ſome other opinions which have been more lately imagined, and which are of a quite oppoſite and contrary nature to all thoſe I have yet explained. The principal author of the firſt of theſe new opinions is Mr. Lavoiſier, whom I have frequently had occaſion to name as the author of many excellent experiments upon elaſtic fluids, as the ſubjects of chemical inveſtigation.

Mr. Lavoiſier was induced to form this opinion chiefly by a number of facts obſerved in the inflammation of bodies. Some of theſe have been already touched on occaſionally, but muſt now be more particularly inſiſted on.

You will find the detail of theſe facts in a ſeries of diſſertations, publiſhed in the *Memoirs of the Academy of Sciences*, particularly in the volumes 1781, 1782, 1785;—in his *Opuſcles Chymiques* publiſhed in 1777, and in his *Elements of Chemiſtry*.

He remarks, that although it has been hitherto ſuppoſed by the chemiſts that a ſubtile kind of matter flies off from bodies, or is ſeparated from them, during their inflammation, no perſon has been able, either to exhibit this common ſubſtance by itſelf, or to ſhew that the body, which was ſuppoſed to ſuſtain this loſs of matter, ſuffered any diminution of its weight. Juſt the reverſe appears, in the greateſt number of experiments, when the inflammable body is of ſuch a nature, that we can collect accurately together all the inflammable matter that is left after the inflammation is over. In ſuch caſes, we always find that this matter exceeds in weight the inflammable body from which it was produced. This fact alone had long occaſioned many to doubt of the exiſtence of a principle of inflammability.

But further, among the numerous experiments which have been made of late upon different kinds of aëreal fluids, ſeveral have been made by Mr. Lavoiſier, in which the inflammable bodies were expoſed to the action of *meaſured quantities* of air, in cloſe veſſels. They were burnt, in part, and nothing was loſt or gained by the whole apparatus. This was weighed with moſt ſcrupulous accuracy before and after the inflammation. But the inflammable body was found to have gained a quantity of weight proportioned to the quantity that had been burnt. Moreover, the air was found to be diminiſhed both in bulk and in weight. That a quantity had been abſorbed by the burning body, or had ſomehow diſappeared, was evinced by opening the veſſels under water. The water ruſhed in, and occupied the room of the abſorbed air. The ſpecific gravity of the remainder being examined and compared with the diminution of room, it appeared that the air remaining alſo weighed leſs than the air before the inflammation; and, laſtly, it was found that the loſs of weight in the air was exactly equal to the augmentation of weight in the remains of the inflammable body.

The moſt ſimple, elegant, and unexceptionable experiment to this purpoſe, is that of F. Beccaria, of Turin. Two ſmall glaſs matraſſes

were joined hermetically by the necks. One of them contained a ſmall quantity of an inflammable body which emitted no vapour in burning. The reſt of the ſpace in both veſſels was filled with vital air; and the veſſels were then ſealed up and carefully weighed. This apparatus was accurately poiſed on an axis, ſo as to vibrate like a common balance which is in equilibrio. A burning-glaſs was now employed to kindle the body, and to keep up the combuſtion as long as poſſible. It was obſerved, that as ſoon as the combuſtion had proceeded a very little way, that end of the balance which contained the burning body began to preponderate. When the burning could be maintained no longer by the action of the burning-glaſs, the balance remained in a very oblique poſition, ſhewing a great addition of weight on the ſide of the burning body. But, as the heat may be ſuppoſed to have expanded that arm of the balance, the whole was allowed to grow as cold as at the firſt. It required about 13 grains to be laid on the other end to reſtore the equilibrium.

Here, therefore, is an evident transference of matter from one end of the apparatus to the other. For, when the apparatus was again weighed, it was found of the ſame weight as at firſt. The veſſels were now opened, and air ruſhed in: It was again weighed, and had gained five grains. The aſhes or remains of the body were now carefully collected and weighed. They were found ſeven grains heavier than before.

Nothing can be conceived more convincing and unexceptionable than this experiment, as a proof that, in the inflammation of this body, it had united to itſelf part of the air contained in the two veſſels. In other experiments made by Mr. Lavoiſier and his copartners, contrived for aſcertaining the preciſe quantities of air conſumed or combined, and the weight gained, it was found that the one was preciſely equal to the other.

It was chiefly on theſe facts that Mr. Lavoiſier founded his new theory of inflammation and combuſtion. He was of opinion that there was no ſuch thing as a principle of inflammability, the phlogiſ-

ton, aſſumed by the chemiſts, nor any ſeparation of a ſubtile principle from bodies, in the act of their inflammation. The very reverſe of this happens, ſays he; the inflammable body ſuſtains no loſs, but receives a conſiderable addition of matter, which is now ſtrongly combined with it, and, during its combination, produces a total change in its nature and qualities, making it appear a ſubſtance of a quite different kind from what it was before.

The matter thus combined with the inflammable body is ſuppoſed by Mr. Lavoiſier to be the baſis, or ponderable part of vital air. He conſiders this air as a compound of this matter, and of the matter of heat, or *calorique*, which calorique is ſo combined with the other matter as to give it the form of an elaſtic fluid, not condenſable by cold, like the vapour of water, but requiring the application of ſome *proper* ſubſtance, for which it has a ſtronger attraction than for calorique. An inflammable body is a proper ſubſtance; but a certain high temperature is neceſſary for enabling them to act on each other. The baſis of vital air then combines with the inflammable body; and the calorique is allowed to eſcape, in the ſame manner that fixed air is allowed to eſcape, when a mild alkali combines with an acid. The heat thus let go is ſufficient to enable the adjoining particles of the inflammable body to act upon, and decompoſe more vital air, and beſides, to heat all ſurrounding bodies.

This opinion of inflammation, and of the change which inflammable bodies undergo, was held by Mr. Lavoiſier as proved by the moſt convincing experiments. For *1ſt*, It is proved that vital air is abſorbed during its action on inflammable ſubſtances; *2dly*, Many of thoſe ſubſtances which have been burnt, or have been expoſed to the action of air and heat, ſo as to ſuffer a change ſimilar to inflammation, can afterwards be made to afford, by means of heat, very conſiderable quantities of vital air. For the proof of this, Mr. Lavoiſier refers to thoſe very experiments in which Dr. Scheele ſuppoſed that ſuch bodies decompoſed the heat applied to them. La-

voiſier could not conceive that heat could be decompoſed in any of our experiments; and maintains that it acts ſimply by expelling the vital air from ſuch bodies in which it is contained, by furniſhing what is to be its latent heat when it is in its elaſtic gaſeous form.

Mr. Lavoiſier further ſays, that it has long been remarked, with reſpect to inflammable ſubſtances, that the incombuſtible matter into which they are changed during inflammation, is, in the greateſt number of caſes, either an evident acid, or has the qualities and appearances of a matter which contains a quantity of acid combined with it, and which it had an opportunity of getting during the combuſtion. This is eminently the caſe in the combuſtion of ſulphur, of phoſphorus, of charcoal,—from which we obtain the ſulphuric, the phoſphoric, and the carbonic acids. An acid is obtainable from the aſhes or calxes of ſome metals deſtroyed by fire and air; and all theſe calxes are ſimilar to what the metals are changed into by actually combining them with a due portion of acknowledged acids.

Mr. Lavoiſier, therefore, induced by theſe general facts, ſuppoſed that vital air is the general principle of acidity. Although it has not the properties of an acid itſelf, it forms acids of different kinds, by combination with inflammable bodies. Combined with ſulphur, it forms the vitriolic acid,—with charcoal, it forms the carbonic acid, &c. &c. He therefore gave it the name of the oxygenous or acidifying principle. *(See Note 6. at the end of the Volume.)*

As to the heat and light which are emitted from theſe bodies in ſuch quantity during their inflammation, or as Mr. Lavoiſier views it, during their combination with the baſis of vital air, he ſuppoſes that it is extricated chiefly, or rather ſolely, I think, from this air; which, in its aëreal ſtate, contains it in great quantity, in conſequence both of what is neceſſary, as latent heat, for its aëreal form, and alſo becauſe in that form it has a very great capacity for heat, requiring much of it to elevate its temperature any number of degrees.

This theory of Lavoiſier is bold and ingenious: And, aſſuredly, it applies with great facility to explain very many of the facts which belong to this ſubject. We muſt certainly admit as a thing proved by his experiments, that when bodies are inflamed, a great quantity of vital air is combined with them, and increaſes their weight. But there are many chemiſts, and chemical philoſophers, who, although they admit this as a fact ſufficiently proved, are not yet ſatisfied that nothing elſe happens in inflammation. They ſtill ſuſpect, or ſuppoſe, that the burning body ſuſtains the loſs of ſome ſubtile and active principle, (ſuppoſe it heat and light), and that it is the loſs of this principle which diſpoſes them to attract the air, and unite with it ſo ſtrongly as they are known to do. For my own part, I was much diſpoſed to this opinion, on the general tenor of chemical combinations. The uninflammable matter produced by combuſtion is generally a much more active ſubſtance, or has an attraction for a greater number of bodies, than the inflammable ſubſtance had from which it came. This is manifeſt in ſulphur and ſulphuric acid, and many other inſtances. This diſpoſed me to conſider theſe ſubſtances as in a ſtate of greater ſimplicity, when they were ſo much more active on other ſubſtances. But, when I conſidered that inflammation cannot now be viewed as a decompoſition alone, it being now proved that the inflammable body is, in fact, combined with a great quantity of vital air, we cannot ſay that it is reduced to a ſtate of greater ſimplicity than before inflammation: For, admit that it has loſt one principle, it muſt be acknowledged that it has gained another, and therefore the obſerved increaſe of activity does not entitle us to ſay that it is rendered more ſimple. It is a new ſubject, and has new relations; and we really do not know whether theſe are or are not more numerous and cloſe than before *.

* Dr Black uſed to remark in ſome of his courſes, that Mr. Lavoiſier's ſyſtem did not explain the remarkable effect of light on bodies, and that Dr. Lubbock had given ſome

The difficulties, therefore, and objections againſt this theory, are now become ſo few and of little weight, and the experiments which ſupport it are ſo numerous, direct, and concluſive, that it is gaining the aſcendancy over all the others, and becoming the moſt general opinion among the chemiſts.

OBSERVATIONS BY THE EDITOR.

There were, however, ſome points that preſented great difficulties, and almoſt put a bar in the way to the confident adoption of the theory, in the extent in which it was propoſed. For it muſt be remarked, that Mr. Lavoiſier's theory goes much farther than the mere explanation of the phenomenon of combuſtion. He ſtates the baſis of vital air as the principle of acidity,—therefore the combination of this principle with an inflammable body is equivalent, chemically ſpeaking, with the burning of that body. The theory, therefore, embraces almoſt the whole of chemiſtry;—and combuſtion, the moſt remarkable phenomenon of material nature, and almoſt characteriſtic of chemiſtry, is now but a ſubordinate fact,—a particular mode of oxydation. But there were ſeveral effects of the vitriolic and muriatic acids which could not be explained by the theory in this its ſimple form. Moſt fortunately, ſome experiments were made by Mr. Cavendiſh at the very time while this theory was in its cradle, which opened a way out of all the difficulties which then embarraſſed it. The diſcovery of the compoſition of water by Mr. Cavendiſh in 1781, and fully demonſtrated by him in June 1783, was carried

uſeful hints on this ſubject, in his diſſertation *de principio ſorbili*, which alſo profeſſes to be a theory of combuſtion and acidification. But I do not ſee that Lavoiſier is any how bound to explain this phenomenon. Berthollet and others affect to aſſign its mode of action, which is always accompanied with ſeparation of oxygen. And they very frequently explain phenomena by ſhewing that they are really inſtances of this expulſion by means of light.

EDITOR.

to Paris by Mr. Blagden, ſecretary of the Royal Society, and by him communicated to Mr. Lavoiſier, who immediately repeated the experiments, and with great addreſs and ingenuity, applied the diſcovery to his theory; and not only got over the difficulties now mentioned, but by inverting the experiment, and reſolving the water into its conſtituent parts, he gave his principles an influence almoſt unbounded, explaining almoſt all the phenomena of active nature. It is here, much more than in the firſt conception of the theory of combuſtion, that the penetration, the inventive genius, and the ſound judgment of Mr. Lavoiſier are moſt conſpicuous. The preciſe logic, to which he endeavoured always to adhere, would have preſerved Lavoiſier from many errors, into which *his followers*, in all parts of Europe, have frequently fallen,—miſled by precipitant and overweening notions of their own knowledge. The compoſition and decompoſition of water affords a mode of explanation ſuſceptible of ſo many forms, according to the fancy and *the wiſhes* of the employer, that there is ſcarecely a phenomenon of which a ſpecious explanation may not be given in more ways than one.

Dr. Black ſays moſt juſtly, therefore, that ſcience has cauſe greatly to deplore the death of that eminent philoſopher. He always expreſſed a high opinion of Mr. Lavoiſier's genius and ſound ſenſe, but was much diſpleaſed with the authoritative manner in which the junto of chemiſts at Paris announced every thing, treating all doubt or heſitation about the juſtneſs of their opinions as marks of the want of common ſenſe.

But, perhaps, Dr. Black was not a competent judge of the matter. In the courſe of his own diſcoveries, he was ſatisfied with the juſtneſs of his view of the ſubject; and he found himſelf able to communicate his knowledge to his ſtudents by means of very plain arguments, and the moſt familiar and ſimple experiments. He deſpiſed the parade of multiplying experiments and argument; but he employed, with becoming acknowledgment of his obligation, the experiments furniſh-

ed him by Mr. Watt and other friends, in further confirmation of his doctrines. Having ſufficiently inſtructed his ſtudents, he had no farther care, and was contented with that reputation which he enjoyed without ſtruggle, and which he was conſcious of deſerving.

But Mr. Lavoiſier was in a very different ſituation. He ſaw that he was about to operate a complete revolution through the whole extent of chemical ſcience. He could not but foreſee doubt and oppoſition on all hands. Confident of victory (after his happy employment of Mr. Cavendiſh's diſcoveries), the proſpect was very flattering. I may perhaps add to this the genius and character of his nation. This is ſcarcely left in my choice,—for, almoſt at the firſt, the doctrines of Lavoiſier were preached by the aſſociated chemiſts as the ſyſtem of *French chemiſtry*. Mr. Fourcroy, Monge, De Morveau, and others, repeatedly give it this name, with ſome exultation. It was propagated as a public concern; and even propagated in the way in which that nation always chooſes to act,—by addreſs, and with authority. Every thing pertaining to the ſyſtem was treated in council, and all the leading experiments were documented by committees of the academy of ſciences. To accompliſh this purpoſe more effectually, they publiſhed the *Annales de Chymie* in concert, and they formed a new language, with the pretext indeed of improving ſcience, but, in reality, that every thing might be forgotten which did not originate in France. A Swiſs gentleman, affectionately attached to Dr. Black, was in Paris at the time, viz. 1787, and wrote to him in theſe words: "*L'objet qui occupe les chy-*
"*miſtes ſurtout à preſent, c'eſt la nouvelle Nomenclature. Il paroit qu'on*
"*veut par là donner le coup de grace au pauvre phlogiſtique; quant a*
"*l'air fixe il faut qu'elle devienne l'acide carbonique*," &c. The writer had ſurely caught the patriotic flame, otherwiſe he would have recollected that it could not amuſe his friend to learn that his diſcovery, which had led the way, muſt vaniſh with the reſt. The plan was the ſame with that of Fabre d'Eglantine with his new calendar;

and the principle was that of Rabaud,—" *il faut tout detruire,—oui,—* " *tout detruire,—parce qu'il faut tout recréer* *."

Dr. Black diſliked this way of proceeding, ſo unlike ſcience and philoſophy. He diſliked the avowed principle of the nomenclature, thinking it more likely to corrupt ſcience than to promote it; and he began to write ſome obſervations on it, but he ſoon deſiſted.

Some time after this, he had more reaſon to be diſpleaſed, and even to be offended. Mr. Lavoiſier ſaw that his theory of combuſtion depended on the doctrine of latent heat, and was extremely anxious to obtain Dr. Black's acquieſcence. In the courſe of 1789, Dr. Black received two letters from the Marquis de Condorcet, full of reſpect for his " *illuſtre confrére*," (Dr. Black having not long before been elected aſſocié etranger de l'Academie des Sciences). In October 1789, Mr. Lavoiſier wrote to him in theſe words: " C'eſt un des " plus zélés admirateurs de la profondeur de votre genie, et des im- " portantes revolutions que vos decouvertes ont occaſionné dans la " chymie, qui profite de l'occaſion du voyage de Mr. B. à Edin- " bourg," &c.

Learning, by the return of this gentleman, that Dr. Black thought well of his theory, and had introduced it into his lectures, he wrote to him again in July 14th 1790, as follows:

* It is not undeſerving of remark, that not only does this principle or aim of the new nomenclature greatly reſemble that of the new calendar, and the new meaſures of France, but that alſo ſeveral of this chemical convention were alſo aſſiſtants, officially, to Fabre d'Eglantine in his project. La Place was in a high department of public buſineſs. Monge was a miniſter of ſtate, and ere this, had ſigned the death-warrant of his ſovereign. Meunier was a general officer. Morveau was a commiſſary of the convention; and perſecuted with the moſt cruel virulence the nobleſſe of his province, who had twice paid his debts, and given him 24,000 livres to enable him to proſecute his chemical inquiries. He was the chief agent in framing the nomenclature. Haſſenfratz, the publiſher of the nomenclature, and of the ſymbols which he had contrived, was alſo high in office, and moſt active in all the projects of Robeſpierre. It is not, therefore, on light grounds that I have aſſigned the ſame motive to the nomenclature and to the calendar.

EDITOR.

" J' apprends avec une joie inexprimable que vous voulez bien at-
" tacher quelque merite aux idées que j'ai profeſſé le premier contre
" la doctrine du phlogiſtique. Plus confiant dans vos idées que dans
" les miennes propres, accoutumé a vous regarder comme mon maitre,
" j'etois en defiance contre moi même *(credat Judæus Apella)* tant
" que je me ſuis ecarté, ſans votre aveu, de la route que vous avez ſi
" glorieuſement ſuivie. Votre approbation, Monſieur, diſſipe mes
" inquietudes, et me donne un nouveau courage. Je ne ſerai content
" juſqù a ce que les circonſtances me permettent de vous aller porter
" moi même le temoignage de mon admiration, et de me ranger au
" nombre des vos diſciples. La revolution qui s'opere en France de-
" vant naturellement rendre inutile une partie de ceux attachés à
" l'ancien adminiſtration, il eſt poſſible que je jouiſſe du plaiſir de la
" liberté, et le premier uſage que j'en ferai ſera de voyager, et ſur-
" tout en Angleterre, et à Edinbourg, pour vous y voir, pour vous en-
" tendre, et profiter de vos leçons et de vos conſeils."

Dr. Black wrote him a very plain, candid, and unadorned letter in anſwer, expreſſing his acquieſcence in his ſyſtem. Mr. Lavoiſier anſwers this by praiſing in the higheſt terms the elegance of the ſtyle, the profoundneſs of the philoſophy, &c. &c. and begs leave to inſert the letter in the *Annales de Chymie*. Dr. Black, who had been in very poor ſpirits when he wrote that letter, and was much diſſatisfied with its feebleneſs, was diſguſted with what he now conceived to be artful flattery, and refuſed to grant the requeſt. Yet his letter appeared in that work before his refuſal could reach Paris.

This wheedling, in order to ſcrew out of Dr. Black an acquieſcence, on which he put a high value for the influence which it would have on the minds of others, was ſurely unworthy of Lavoiſier. Dr. Black was not only diſguſted with the flattery, but ſeriouſly offended with its inſincerity; and with a ſort of inſult on his common ſenſe, by the ſuppoſition that he could be ſo wheedled, by a man whoſe publications never expreſſed the ſmalleſt deference for his opinions. For, by this

time, Dr. Black had read Mr. Lavoiſier's *Elements of Chemiſtry*, and the various diſſertations by him and Mr. De la Place, publiſhed in the *Memoirs of the Academy*. His name is not once mentioned, even in the diſſertations on the meaſures of heat, where his doctrine of latent heat is delivered and employed as the reſult of Mr. Lavoiſier's own meditations. Nor is he named in thoſe paſſages of the earlier diſſertations, where the characters and properties of fixed air, and of the mild and cauſtic alkalis, are treated of. All appears to be the train of Mr. Lavoiſier's own thoughts, for which he was indebted to no man. Such inconſiſtency with the deference expreſſed in the above cited letters, provoked Dr. Black to ſuch a degree, that he reſumed his critique on the nomenclature, and began to expreſs his diſſatisfaction with ſome parts of the theory, and his utter diſapprobation of the unſcientific and bullying manner in which the French chemiſts were trying to force their ſyſtem on the world. But, by this time, his health was become ſo delicate, that the leaſt intenſity of ſtudy not only fatigued him, but made him ſeriouſly ill, and forced him to give it up. I ſaw him but ſeldom at this time, being then in very bad health myſelf; but had this information from Dr. Hutton, who ſhared all his thoughts. It was at this time that he gave up his intention of making a conſiderable change in the arrangement of his lectures, and that he expreſſed himſelf, as I have related, at the end of the introduction to the particular doctrines of chemiſtry. But ſtill, notwithſtanding the contempt which he expreſſed for the folly of a man who had tried, by fulſome and inſincere flattery, to obtain what he had given him unaſked, by teaching all his doctrines, Dr. Black conſidered the death of Lavoiſier as a great loſs to the ſcience *. He expected much from his penetration

* This ornament of France fell a ſacrifice to the ambition of the very men whom he had aſſociated with him in his labours and honours. They were all perſons in office, or national repreſentatives, and, in that character, gave their conſent (to ſay the leaſt of it) to his ſentence of death. But he was rich, and loyal,—they were——and——

and ſound ſenſe; and he conſidered him as the only perſon who could keep his followers right, by checking their precipitant manner of proceeding.

Profeſſor Lichtenberg, of Gottingen, a man of extenſive and accurate knowledge in every department of natural ſcience, gives an entertaining and inſtructive account of the introduction of theſe doctrines into Germany. It is to be found in his preface to the edition 1794, of *Erxleben's Introduction to Natural Philoſophy;* as alſo in the *Literary Magazine* of Gotha. Great heſitation, doubt, and objections, were to be expected in Germany, the native ſoil of chemiſtry, and the reſort of all who wiſhed to perfect themſelves in mineralogy. The new doctrines were even received with averſion and diſguſt. This, he ſays, was chiefly owing to the character of the nation from whence they came. The Germans, who had been accuſtomed to conſider themſelves as the chemical teachers of Europe, could not bear to hear the opinions of their maſter, Stahl, treated with contempt; to be told by Frenchmen, living among them for inſtruction, that the principles of Stahl were ſuch as no man could embrace who had a ſpark of common ſenſe; to be told, in letters from France, that the principle of Stahl was a *mera qualitas;* a *mera contemplatio*, a fancy of the brain, which diſgraced any man who entertained it for a minute; and to have it added, with ſaucy politeneſs, *dulci requieſcat in pace!* But what moſt provoked them, was the pitiful triumphs of victory in which the French chemiſts indulged themſelves. He ſays, that when the aſſociation had finiſhed their experiments on the compoſition and decompoſition of water, which filled up all the gaps of the ſyſtem, they had a ſolemn meeting in Paris, in which Madame Lavoiſier, in the habit of a prieſteſs, burned on an altar Stahl's *Chemiæ dogmaticæ et Experimentalis Fundamenta*, ſolemn muſic playing a *requiem;* and he remarks, that if Newton had been capable of ſuch a childiſh triumph over the vortices of Des Cartes, he could never be ſuppoſed the man who wrote the *Principia.* I might add, that if Newton or Black had ſo exulted over

Des Cartes and Meyer, their countrymen would have concluded that they were out of their ſenſes. But at Paris every thing becomes a mode, and muſt be *fêté*. Dr. Black's nice ſenſe of propriety made the intriguing conduct and arrogant aſſumption of all merit by the French chemiſts extremely offenſive to him, and has probably made him ſo minutely careful to place in full view all the labours and diſcoveries of the Britiſh and Swediſh chemiſts, particularly thoſe of Cavendiſh and Scheele, which ſupplied the great facts on which the ingenious doctrine of Lavoiſier is eſtabliſhed.—I flatter myſelf that this ſtatement of facts, and theſe reflections, will not be thought improper or unimportant.

We ſhall now proceed to take a nearer view of the different kinds of the inflammable ſubſtances.

The moſt remarkable inflammable ſubſtances may be arranged under ſeven titles, which are theſe:

1. Inflammable air.
2. Phoſphorus.
3. Sulphur.
4. Charcoal.
5. Spirit of wine.
6. Oils.
7. Bitumens.

Of theſe, the firſt four may be called SIMPLE INFLAMMABLES, becauſe we have not not been able to reſolve them into ſubſtances more ſimple. Ardent ſpirits, oils, and bitumens, are very eaſily reſolvable, and are vaſtly complex.

I.—INFLAMMABLE AIR.

The firſt in this order, the *gas pingue* of Van Helmont, the ſubſtance which has been long known by the name of INFLAMMABLE AIR,

is certainly the moſt ſubtile and moſt highly inflammable of all the bodies that belong to this claſs. The peculiar phenomena and conſequences of its inflammation, as well as what was obſerved in combining it with other bodies, cauſed it to be conſidered by ſome authors, of the firſt rank among chemiſts, as the true phlogiſton of the chemiſts, or as totally made up of their principle of inflammability. This opinion of it was formed by Mr. Cavendiſh, and by Mr. Kirwan, who publiſhed his thoughts on this ſubject in the Philoſophical Tranſactions for the year 1782; and, after that time, in a ſeparate volume. And Dr. Prieſtley had nearly the ſame opinion of it. But, ſince that time, Mr. Kirwan has abandoned the ſuppoſition of a phlogiſton in the inflammable ſubſtances.

This inflammable ſubſtance has been known a long time. Indeed, it muſt have been known as early as any conſiderable progreſs was made in the knowledge of nature and chemiſtry. Van Helmont calls it *gas pingue*. It is not always preciſely the ſame. There are great varieties of it, occaſioned by impurities or admixture, and ſome of theſe are found in almoſt all that is gotten already formed by nature; but it may be alſo produced, or extricated from different ſubſtances artificially, by a variety of chemical operations.

It is frequently met with in mines, eſpecially in thoſe of coal, and renders the working of them extremely dangerous. It is called by the miners the *fire-damp*, or *wild-fire*. It is alſo extricated or produced from animal and vegetable ſubſtances, when theſe are decompounded and deſtroyed by fire or putrefaction. And hence it is that there is a ſmall quantity of it mixed with the black mud of putrid ditches and marſhes in ſummer, which mud is compoſed of the putrid remains of vegetables and animals. If a ſtick be thruſt down to the bottom of ſuch ditches, and the mud be ſtirred, a number of air-bubbles riſe to the ſurface of the water, and a candle being held near it at the ſame time, the air will take fire, and give a momentary flaſh. Or it may be collected in inverted glaſſes filled with the water, and may

be afterwards fired. This was firſt diſcovered by the celebrated Dr. Franklin *. The knowledge of that kind of it which occurs in coal mines muſt have been as early as the art of mining coal.

In thoſe coal mines which are infeſted with it, it is obſerved to iſſue from crevices of the ſtrata in the ſubterranean chambers of the mine, in form of a vapour or aëreal fluid, which, mixing with the air of the mine, is ſaid to produce ſome degree of miſty appearance in it. And, when it is not very abundant, it does not communicate any unwholeſome quality to that air.

The greateſt danger attending it proceeds from its high degree of inflammability; the ſmalleſt flame, as that of a candle, being ſufficient for firing the largeſt quantities of it, with a violent exploſion. And, unfortunately, in thoſe places, no work can be done without artificial light. In ſome mines they are obliged to work by the dull light produced by a piece of flint rubbing againſt the circumference of a ſteel wheel, which is jagged like a file. When it happens unfortunately that conſiderable quantities take fire, the inflammation of it is as rapid and violent as that of gunpowder; and it produces an exploſion almoſt like thunder, and which is attended with moſt dreadful effects. In ſome caſes, the whole works of the mine are demoliſhed, and numbers of miners killed, and ſometimes blown up, with heavy machinery, to a conſiderable height in the atmoſphere. Theſe ſhocking effects are produced by the great expanſion which the flame occaſions in the air and vapour that is mixed with it. The inflammable air itſelf does not expand in the act of inflammation, but, on the contrary, collapſes into very ſmall bulk; but it is then mixed with the vapour of water, and with azotic gas, both of which it expands, and forces them along

* Van Helmont mentions this, and adds, "Stercoraceus flatus, per flammam candelæ tranſmiſſus, tranſvolando accenditur, ac flammam diverſicolorem, inſtar iridis exprimit." (*De Flatibus*, § 49.)

It is even produced by ſome living plants. The *Dictamnus Fraixnella* emits it from its flowers in ſuch abundance in a calm evening, that it may be ſet on fire by a candle, nay, take fire of itſelf.

the long and narrow chambers of the mine, and ſweeps every thing along with it, juſt as the firing of gunpowder accelerates a bullet along the barrel of a muſket.

In ſome mines, in which the ſources of this vapour are but ſcanty, and in which it requires a long time before a conſiderable quantity is collected, they preſerve themſelves from danger by firing it frequently, and therefore, by ſmall quantity at a time. They obſerve the places in which it collects, which are always over their heads, or in the hollows of the roof of their ſubterraneous workings, it being the rareſt or lighteſt of all fluids that we know. When pure, it is but one-fifteenth of the weight of an equal bulk of common air. At ſtated times they ſet fire to it with a candle faſtened to the end of a long ſtick, or tied to the middle of a long ſtring, the two ends of which are held and drawn by two men at a diſtance from the ſpot.

But there are ſome coal mines in which the ſources of it are too abundant to be eaſily managed in this manner. In theſe they have recourſe to another method by which it is conſtantly carried off and deſtroyed, namely, by having wooden trunks or pipes conducted along the roof of the workings, (ſo the chambers of a mine are named) with branches carefully leading to all the places where this air moſt copiouſly gathers. All theſe trunks meet at the bottom of a ſhaft, and from thence a great trunk is carried up, to the ſurface, in a corner of the ſhaft, where it enters into a ſmall chamber having a tall chimney. A fire is kept in this chamber, and air is ſupplied to it only from this trunk. The warmth of the chamber and chimney produces a current, and thus the air is collected from all parts of the mine. When the inflammable air is very copious, it is ſaid to burn at the top of the trunk, and produce heat enough, without any more fuel, for maintaining a continual flame and current.

There are ſeveral places on the Continent, particularly in Italy, where a vapour of this kind breaks out at the ſurface of the earth, and is liable to take fire, producing a lambent flame. In England

there is an example or two, recorded in the Philoſophical Tranſactions. In Perſia, there is a ſmall diſtrict, where the inhabitants collect it into one place by means of covered gutters, and there ſetting fire to it, uſe it for dreſſing their victuals, and even for lighting their huts. I doubt much that theſe are exaggerated accounts; for this extremely rare fluid gives ſo little heat, that its flame ſcarcely will ſcorch the hand; and the light is proportionably feeble. When it riſes through the water of wells in bubbles, they burſt at the ſurface; and when they are very copious, ſo that while one is burning another riſes cloſe by it, then a candle being applied, flame catches at the ſurface, and continues with a crackling noiſe. In the burning well at Chittagong, in India, it takes fire of itſelf after having been extinguiſhed by daſhing pailfuls of water in it.

Beſides theſe examples, where it is formed by nature, I ſaid that it is alſo very frequently produced from different ſubſtances artificially, by a variety of chemical operations.

The examples of this are too many to admit of my enumerating them all here *. I ſhall for the preſent mention only one ſimple proceſs by which this gas is produced in a high degree of purity. We need only to mix ſome of the ſtrong ſulphuric acid with about eight times its weight of water, and throw into the mixture ſome very clean iron filings, equal in weight to half of the ſulphuric acid. The iron is diſſolved with ebullition and heat, and a great quantity of this aëreal

* We muſt, however, carefully diſtinguiſh the inflammable air of which Dr. Black is now ſpeaking, from a vaſt multitude of inflammable vapours which nature and art produce. Oils, vinous ſpirits, and many other inflammable ſubſtances, can be changed into vapour by heat, and the vapours are inflammable, of courſe. But we are now ſpeaking of a *peculiar ſubſtance*, which we have never been able to decompound, and therefore aſſume as a ſimple ſubſtance. This, when pure, is always the ſame, in whatever way we procure it;—the other inflammable and incondenſible airs are not ſimple, but yield, by burning, carbonic acid gas.

EDITOR.

inflammable ſubſtance ariſes from the ſolution, and may be collected in veſſels filled with water, and inverted into a veſſel of water.

This has been long known to the chemiſts, and it was uſual with them, when they had occaſion to diſſolve iron in the ſulphuric acid, to amuſe themſelves by firing this vapour, to make it give exploſions, or burn in different ways.

But no other experiments were made to inveſtigate its nature in other reſpects, until after I had made the experiments on quicklime, and on fixed air, which I have already deſcribed to you.

I had then the curioſity to try whether this gas was attracted by alkaline ſubſtances, in the ſame manner as fixed air is attracted by them; and I ſatisfied myſelf that it was not attracted by them. I was alſo accuſtomed to exhibit to my pupils the different manner in which it burns when pure or when mixed with air. When it iſſues pure, in a continued ſtream, from a pipe, a candle applied to the jet will kindle it, and it will continue to burn quietly as faſt as it iſſues; —but not till it is out of the pipe, becauſe it burns only where it is in contact with vital air. But, if the veſſel from which it iſſues contain vital or atmoſpheric air alſo, mixed all over with the inflammable air, then a candle applied to the mouth will fire the whole in an inſtant, with an exploſion that will burſt the veſſel, if not very ſtrong.

The Honourable Mr. Cavendiſh, ſome time after, (anno 1766) publiſhed in the Philoſophical Tranſactions, experiments on this and other kinds of air; by ſome of which he aſcertained with great ingenuity and exactneſs, the denſity of different airs or gaſes, compared with that of common air. He found that the gas we are now ſpeaking of has a ſurpriſing degree of rarity. It weighs leſs than the one-tenth part of the weight of an equal bulk of common air. Therefore, if you would keep it in an open veſſel for any immediate experiment, you muſt keep the mouth of the veſſel down, and the bottom uppermoſt. If you fire it in this ſituation in a tall glaſs, and immediately turn it up, the inflammable air riſes in a beautiful burning column.

As ſoon as this diſcovery of its great levity was publiſhed, it pointed out an obvious conſequence, which immediately occurred to me,—that if a quantity of gas could be confined in a veſſel, or other containing matter that was exceedingly thin and light, the gas and veſſel together might form a maſs lighter than an equal bulk of common air, and which would riſe in the atmoſphere, as cork does in water. I therefore thought of providing a veſſel or envelope for this purpoſe; and that which firſt occurred to me was either the allantoïs or the amnion of a calf, which I procured, but not getting it ready ſoon enough to ſhew the experiment at the time I intended it, I did not exhibit it, but mentioned it in my lectures as a thing which might be found practicable, though I did not ſee that it could be applied to any uſe. I did not imagine that the ſame idea would have been improved to ſuch a degree as it was afterwards in France. All the world has been amuſed with their air-balloons, which they ſoon made of ſuch a monſtrous ſize as to lift very heavy weights to a great height in the air *. Of theſe balloons two kinds have been made uſe of in their experiments.

Mr. Mongolfier, a paper-maker at Lyons, firſt thought of making a balloon ſo light as to float in the air, merely by burning ſhreds of paper or ſtraw under the mouth of a great globe of paper or thin linen. Having ſucceeded, he made another ſo large as even to carry up a conſiderable weight; and, in order to keep it afloat, he hung under it a choffer, in which the fuel was renewed by the perſons who were carried up by it. He made them of 40 feet diameter, and 70 feet high, which carried ſix or ſeven perſons.

When accounts of this contrivance reached Paris, the inhabitants of

* It is worthy of notice, that Dr. Mayhow, in his diſſertation *de ſpiritu nitro-aëreo*, deſcribes experiments which have certainly been made with oxygen gas. He alſo gives very plain hints of balloons filled with a ſubſtance much lighter than air, which he ſays was known to him.

EDITOR.

which are keen for amuſement, Mr. Charles, an intelligent chemiſt, immediately recollected the immenſe ſuperiority of inflammable gas for a project of this kind, and readily found men of fortune and pleaſure to contribute to the great expence of ſuch entertainment, which in ſeveral caſes amounted to more than 500l. His balloons were made of a thin but ſtrong ſilk, made air-tight by varniſh, and they were filled with gas produced from iron diſſolved in vitriolic acid,—but ſo far from pure, that it was not more than ſeven times lighter than common air. Indeed, this is as much as ſhould be reckoned on, becauſe the iron employed is generally rubbiſh, ruſty, and even caſt iron, which produce much fixed air. His balloons were much ſmaller than Mongolfier's, but roſe to a very great height, ſometimes almoſt three miles.

Since, in order merely to float, the weight of the balloon and air muſt not exceed that of common air, there is a minimum of ſize, depending on the weight of a ſquare foot of the covering. The ſmalleſt balloon of thin poſt paper, that will merely float, is ſeven inches in diameter. Strong poſt paper muſt not be leſs than thirteen inches,—oiled ſilk will float, if two feet ten inches,—and oiled linen, if four feet ſix inches. An oiled linen balloon, of nineteen feet diameter, will lift a weight of 250 pounds a mile high; and other ſizes will lift nearly in the proportion of the cubes of the diameters, when they are large.

Theſe experiments gave riſe to a number of projects for performing voyages with ſuch machines; though it muſt have appeared evident to any perſon who underſtood their nature, and conſidered it well, that they were totally unfit to be applied to any ſuch purpoſe.

That air balloons cannot be applicable to the purpoſe of making voyages, or of traverſing the air in any direction that we pleaſe, is evident, by theſe reaſons:

1*ſt*, We cannot find a power that will be ſufficient for moving

ſuch bulky maſſes through the air, and that can be lifted up by them. The force of one man, or of any number of men which the balloon can lift, is very far from ſufficient for moving it with the requiſite velocity for performing voyages, even in a perfectly calm air. And if there be the leaſt of a contrary wind, they could not move it an inch in the propoſed direction. All this is true, even ſuppoſing that the whole force of thoſe men could be employed or exerted in order to move it. But how are we to employ or exert this whole force, when the balloon is ſuſpended in mid air? Had the men ſome fixed immoveable body, towards which they could draw the balloon with ropes, or from which they could puſh it with poles, their whole force might be exerted. But they have nothing to puſh it from, except the empty air, (as it is ſtyled by the poets) a fluid ſo rare, that it gives very little reſiſtance. And the force of the men would be moſtly expended in moving their own limbs and the inſtruments, whether oars or wings, with which they ſhould attempt to beat or to puſh that air. When a boat is impelled through the waters by men and oars, the oars are applied to a medium, which, though fluid and yielding, yet gives incomparably more reſiſtance and power to the ſtroke of the oar, than air. It is more than 800 times as denſe as air. And beſides, the boat is formed for moving through the water with the leaſt reſiſtance poſſible. The two machines cannot be compared together.

Some again have thought of the example of ſhips, which can be made to go in different directions with the ſame wind, by ſetting their ſails obliquely to the wind in different poſitions. And they thought that ſome ſort of ſails might be applicable to a balloon. But here again the caſe is totally different. A ſhip has a hold of the water by her bottom and hull while ſhe is impelled by the wind: And the form of the veſſel diſpoſes it to glide eaſily through the water with the prow foremoſt, but to be difficultly moved with the broad ſide. In conſequence of this, it is made to ſail in many dif-

ferent directions with the ſame wind. The balloon has no hold of any thing whatever, but the air or the wind itſelf. It is, therefore, carried along by that air, as a feather would be, and has as little power to reſiſt the action of the air on it as a feather has.

2*dly*, Beſide all theſe, there is ſtill another and an inſuperable reaſon againſt the poſſibility of uſing balloons to make voyages, and to command their motion and direction. They muſt neceſſarily be made of very thin materials, and of the moſt flimſy conſtruction, that they may be ſufficiently light. Now, ſuppoſing we could apply a power to them that could move them with ſufficient velocity, they could not ſupport the impulſe and reſiſtance of the air againſt them while they moved through it. They would immediately be torn in pieces.

In the common manner of uſing them, when no attempt is made to direct or modify their motion, they are ſecure from this accident, being then carried along by the wind as a feather would be; ſo that although they are moved ſometimes with great velocity, they are not expoſed to any violent impulſe of the air on any one ſide of them more than another. They move as faſt as the air itſelf, and the perſons who are in them feel as if they were becalmed.

3*dly*, They cannot remain ſuſpended in the atmoſphere for any conſiderable time.

4*thly*, Another inconvenience, and even danger, to which balloons are expoſed, is a whirlwind, which they ſometimes raiſe, and by which ſome of them have been agitated, with great danger to the aëronauts.

The only uſe to which they have been found applicable, is one which occurred to me, and which I have occaſionally mentioned ever ſince they were contrived, viz. for reconnoitering the poſition and ſtrength of an enemy's encampment, and poſts, in the art of war. It has been common to aſcend ſteeples and riſing grounds for this

purpoſe; but in calm weather, a balloon, ſecured with a rope, can eaſily be made to riſe to many times the height of a ſteeple.

Let us now return to the examination of inflammable air.

Another remarkable property of inflammable air, is its high degree of inflammability *.

The flame of this gas, in its unconfined ſtate in common air, is extremely weak, as is reaſonable to expect from a fluid ſo very rare, that a cubic foot weighs only 37 grains. The beſt way of obſerving it in this ſituation, is to blow up a ſoap bubble with it, and fire it with a candle. A more ſhowy way is to fill with it a tall glaſs, having a movable bottom. It muſt be held with the bottom uppermoſt, otherwiſe the gas will ſoon diſperſe by its great levity. Holding the glaſs upright, and a candle a little way above it, (about twice the height of the glaſs) remove the bottom ſuddenly, and the gas, puſhed up by the air below, will riſe and meet with the candle, and form a beautiful column of lambent flame, not hot enough to ſinge the fineſt down. It burns with a brighter flame at the mouth of a pipe, becauſe it is denſer there, eſpecially if ſtrongly preſſed out, by ſqueezing the bladder which contains it.

* It catches fire by the ſmalleſt ſpark. The moſt trifling electric ſpark is ſufficient. But it ſeems as if the mere elevation of its temperature is not enough; for it is very difficult to fire it by paſſing it through a red hot tube, or by blowing it againſt a lump of ignited, but uninflamed matter. Even in the caſes where we ſucceed, I am doubtful whether it is not by a ſpark of inflammable matter in the act of compoſition, that it is kindled. For I obſerve, that when the pureſt that I could obtain, by diſſolving a metal in muriatic acid, is kindled at the end of a tube, from which it iſſues in a ſtream, the dull flame with which it burns has in the very middle a continual train of brighter ruddy ſparks, which not only ruſh ſtraight forward, but frequently ſplit and dart ſideways, with a momentary brilliancy, like the ſparks of brandiſhing iron. I ſuſpect that theſe are ſcorifications and exploſions. Theſe may be effected by the contact of a red hot tube, and will fire the gas. We know, without being able to explain it, that the action of the electrical ſpark is of the ſame kind. It ſeems to be only a comparative ſecurity which the light from flint and ſteel gives to the miners. Yet I confeſs that I have not been able to fire it in this way. EDITOR.

It burns with more vivacity in vital air, but the difference is not ſo remarkable as one ſhould expect. Yet, on reflection, we muſt be ſenſible that ſo ſmall a quantity of inflammable matter muſt be completely and inſtantaneouſly inflamed, even in common air, with which it readily mixes.

The examination of the phenomena which accompany the inflammation of it in vital air has been productive of ſuch extenſive conſequences, and has ſo enlarged our knowledge of the chemical operations of nature, that I think it neceſſary to give you a hiſtorical account of it, and of the contributions which different authors have made by its means to the general ſtock of knowledge.

Dr. Prieſtley's examination of the gaſeous fluids had exhibited a great number of concrete ſubſtances brought into an aëreal form, contrary to all our former conceptions of things. But this particular gas occaſioned a diſcovery ſtill more unlooked for. A ſubſtance which had been conſidered as an element, not only in the very dawn of natural philoſophy, but which had maintained the character undiſputed by the moſt acute and penetrating chemiſts of this moſt inquiſitive age, is now found to be a compounded ſubſtance, and its ingredients fairly put into our hands.

Dr. Prieſtley was occupied with the examination of inflammable air, and tried the effect of almoſt every ſubſtance on it: He alſo tried the effect of the electrical ſhock and ſpark. As he expected, he found that it was expanded by it, but could not be inflamed by it in cloſe veſſels, unleſs mixed with common air. In this ſtate it fired with a violent exploſion. He was particularly ſurpriſed at the great diminution of bulk,—finding that a mixture of one part of inflammable air, and two of common air, might be made to contract into half the bulk, and that it was now phlogiſticated air. Having already diſcovered the vital air, he fired a mixture of theſe, and found that when two parts of inflammable air and one of vital air were exploded together, it collapſed into almoſt nothing, or nearly the whole diſappeared. Mr.

Warltire, who aſſiſted in theſe experiments, obſerved that the inſide of the veſſel in which the deflagration had been made, was always moiſtened with dew. Dr. Prieſtley naturally aſcribed this to moiſture, which probably adhered to the airs employed, as they were always produced in proceſſes in which water in ſome form or other was preſent. Theſe experiments were made about the year 1782.

My friend Mr. Watt had taken great intereſt in theſe experiments of Dr. Prieſtley's, and communicated his opinion concerning them to Mr. De Luc, in a letter dated April 1783. This letter is, in part, a tranſcript of one written ſome months before to Dr. Prieſtley, with a deſire that it ſhould be communicated to the Royal Society. In this he declares his opinion, that the water obſerved in theſe experiments aroſe from the combination of the two airs; and ſays, that water is the compound of dephlogiſticated or vital air, and inflammable air, deprived of their latent heats; and that dephlogiſticated air is water deprived of its phlogiſton (i. e. of the inflammable air) in an aëreal form, that is, ſaturated with the matter of light and heat. Dr. Prieſtley did not communicate this to the Society, becauſe (he ſays) ſome experiments which he had made ſince he ſaw Mr. Watt, were directly contrary to this opinion.

Dr. Prieſtley's experiments excited the attention of the Honourable Mr. H. Cavendiſh, and recalled to his mind his own obſervation of the moiſture in the veſſels in which he had exploded theſe two airs. Theſe experiments had been begun in the ſummer 1781, and were continued from time to time, along with thoſe by which he had diſcovered the compoſition of the nitrous acid. He immediately ſet about repeating the exploſion of dephlogiſticated and inflammable airs by the electrical ſpark; and in May 1783, he found that when ſix parts by weight of pure dephlogiſticated air were exploded with one of inflammable air, they diſappeared entirely, and that the reſult was a quantity of pure water, equal in weight to the airs employed. The utmoſt care had been taken to free the airs made uſe

of, by making them pafs through the dry muriat of lime. The veſſel burſt in ſeveral of his experiments, becauſe, in the inſtant of exploſion, the vapour of the produced water was expanded by the heat extricated from the airs. Much of this heat, to be ſure, was expended in giving theſe the vaporous form, or ſupplying it with latent heat. But the veſſel was inſtantaneouſly heated, ſhewing that the heat contained in the two airs more than ſufficed for this purpoſe. Theſe experiments were publiſhed in the Philoſophical Tranſactions for 1784.

Such curious experiments, and ſo intereſting a reſult, could not remain a ſecret, had ſuch a thing been intended. But there was no ſuch intention. Mr. Blagden, ſecretary of the Royal Society, went to Paris in June 1783, and communicated theſe experiments of Mr. Cavendiſh to Mr. Lavoiſier, and his aſſociates, De la Place, Meunier, Monge, &c. knowing that they were much intereſted in their reſult, which was ſo intimately connected with the new theory which Mr. Lavoiſier was then eſtabliſhing.

Accordingly, Mr. Lavoiſier, who ſaw the immenſe conſequence of this diſcovery to his theory, immediately ſet about repeating the experiment of compoſing water by the combination of the two airs; and in September 1783, with the aſſiſtance of Mr. Meunier, effected the compoſition in a way that admitted no doubt. Inſtead of effecting it by the exploſion of a few grains of gas, which is all that a manageable veſſel of glaſs can contain, he did it by admitting two fine ſtreams, one of each gas, into a balloon, through two tubes leading from large magazines of gas, and having their points ſo near to each other that the ſtreams mixed immediately. The gaſes were ſupplied *in the due proportion* by regulated preſſures of water on the gaſes in the magazines. While the pipes were thus delivering the due proportion of gas, it was fired by an electric ſpark, and the flame continued as long as the gaſes continued to be ſupplied. In this manner, very great quantities of gas were inflamed,

ſo that the unavoidable errors in the ultimate meaſurement bore a very ſmall proportion to the whole. At the end of the operation, there was commonly a remainder of carbonic acid and of azote, from which it is almoſt impoſſible to free the gaſes completely.

The reſult of this capital experiment was perfectly conformable to that of Mr. Cavendiſh. When the exact proportion of gaſes was attained, the reſult was water ſlightly acidulated. This proportion was fourteen parts by weight of inflammable air, and eighty-ſix of vital air.

Mr. Monge made a ſimilar experiment at Mezieres, in June 1783, with the ſame reſult, and (he ſays) without having heard of the experiments of Mr. Cavendiſh, or thoſe of Lavoiſier and Meunier. The vital air employed weighed five ounces five drachms twelve grains; and it left thirty-five grains of water in the muriat of lime through which it paſſed. The inflammable air weighed ſix drachms thirty grains, and left forty-four grains of water. Therefore the quantities which really burned were—

	oz.	dr.	gr.
Vital air - - -	5	4	49
Inflammable air - -		5	58
	6	2	35
Mixture remaining unburnt -		6	24
Quantity of gaſes compounded -	5	4	11
Water produced - -	5	4	41

This exceſs of thirty grains muſt be aſcribed to errors in the eſtimation and weighing of the different articles. The water was not perfectly pure, but contained five grains of nitrous acid in each ounce.

Some time after, in 1798, Mr. Seguin again repeated this experiment, expending 25582 cubic inches, or nearly two hogſheads of

inflammable air, and 12457 of vital air. The firſt weighed 1039$\frac{1}{3}$ grains, and the ſecond 6210, amounting to 7249$\frac{1}{3}$ grains; and the water obtained amounted to 7245 grains, which is nearly 5944 grains Engliſh troy, about three-fourths of an Engliſh wine pint. No greater loſs than four grains, in an experiment of this kind, is an exactneſs of which one has no idea. I doubt not, however, as this relation is a formal report from the Academy of Sciences, but that the experiment was very accurately performed, and the reſult extremely ſatisfactory.

Another experiment ſtill was made by Le Fevre de Geneau, in which 35085 inches of oxygenous gas, and 74967 of inflammable gas were burned, weighing two pounds three ounces and ſixty-four grains, (French *poids de marc*), and two pounds three ounces and thirty-three grains of water were obtained, containing twenty-ſeven grains of nitrous acid. Still more trials were made by Von Hauch, employing 3000 and 5000 inches, alſo with 1600 and 3000. The aim of ſo many laborious and expenſive trials was, to hit the proportion of gaſes ſo exactly that the water ſhould be pure;—but it was always contaminated with nitrous acid. This valuable information, however, was obtained from it,—that it was indifferent what acids had been employed for obtaining either of the gaſes. *Nitrous acid only* was found in the water.

A very candid and intelligent account is given of all the diſcoveries relating to the inflammation of theſe two gaſes in the tranſlator's preface to the ſecond edition of Fourcroy's Chemiſtry.

Mr. Cavendiſh, the original author of theſe experiments, and of the doctrine deduced from them, concluded that water is a compounded ſubſtance, and that its conſtituent parts are vital air and phlogiſton, viz. inflammable air. For at that time Mr. Cavendiſh was of opinion that inflammable air is the true phlogiſton of the chemiſts.

But, although Mr. Cavendiſh is the undoubted author of this deci-

ſive experiment, and, with Mr. Watt, is alſo the author of the important doctrine of the compoſition of water, Mr. Lavoiſier has the ſtill greater merit of ſeeing this propoſition *in all its importance.* *This* incited him to undertake theſe laborious and expenſive experiments, which confirmed thoſe of Mr. Cavendiſh beyond a doubt; and he had alſo the ſagacity to perceive *immediately*, that by means of this propoſition, he ſhould extricate his great ſyſtem from difficulties and objections which I think would otherwiſe have been unſurmountable, and even to convert them into ſtrong arguments in its favour, and make them the means of extending it to chemical facts, and to the great operations of nature, which ſeem otherwiſe inexplicable.

Thus excited, Mr. Lavoiſier was not contented with having demonſtrated that the exploſion of vital and inflammable airs produce pure water, but, in September 1783, with the aſſiſtance of Mr. de la Place, he confirmed this demonſtration of the compoſition of water by decompoſing it, and producing its ingredients in a ſeparate ſtate. I ſhall therefore relate to you Mr. Lavoiſier's experiments on this ſubject, and the manner in which he reaſoned from them.

His firſt experiment conſiſted in ſimply putting ſome clean filings of the pureſt iron into diſtilled water, which filled a jar ſtanding in the ſame water. After ſtanding ſome days, a quantity of pure inflammable air is found collected in the top of the jar, and the iron is found corroded and black,—and when carefully dried, weighs more than before, and if expoſed to heat in a retort, affords vital air. The iron, ſays he, attracts the oxygen of the water, and the inflammable air is ſet at liberty.

The ſecond experiment is more remarkable. A ſmall glaſs retort, having a very long neck, and holding an ounce or two of water, is ſo placed that this neck paſſes through a choffer of live coal, by which it is maintained red hot, while the water in the retort is made to boil gently. The vapour is collected and condenſed in a proper pneu-

matic apparatus. It is found to be pure water, and precisely equal in weight to the water boiled off.

But, having put into the neck of the retort 28 grains of pure charcoal, and repeated the distillation, he found that the charcoal had vanished, and that the water collected in the receiver was $86\frac{4}{10}$ grains less than the water which had quitted the retort, which was $113\frac{7}{10}$ grains. But he found in the pneumatic vessel connected with the retort and receiver, 100 grains of carbonic acid, and 12 of inflammable air. Here, therefore, it appears that the carbone had attracted the oxygen of the water, and thus decomposed it. The quantity of the carbonic acid was determined by passing the whole elastic matter obtained through milk of lime, which absorbed it. Now 100 grains of carbonic acid had been long before proved, by his experiments, to contain 72 grains of oxygen. This quantity of oxygen, combined with $13\frac{7}{10}$ grains of inflammable air, would compose $85\frac{7}{10}$ grains of water. There appeared, therefore, a deficiency of $1\frac{7}{10}$ grains of inflammable air.

In a third experiment, he placed, instead of the charcoal, 274 grains of fine soft iron wire, loosely coiled. At the end of the operation, he found the iron changed into black iron scales, such as are found to fly from iron in forging, and 85 grains heavier than before. In the receiver he found 15 grains of pure inflammable air; and there was a loss of 100 grains of water. Now 85 grains of vital air, when united by inflammation with 15 grains of inflammable air, should compose very nearly 100 grains of water.

The conclusion from these experiments is so evident that it is needless to go through it minutely. I have not used the precise numbers which occurred in Mr. Lavoisier's experiments, but such numbers *in the very same proportions* as enable you to make the calculations without any trouble. Mr. Lavoisier and his associates give the name HYDROGEN to the ponderable basis of inflammable air, (which they

call HYDROGENOUS GAS), becauſe, when combined with oxygen, it compoſes water.

Notwithſtanding this body of evidence, ſome chemiſts, unable to relinquiſh their habits of explaining every thing by phlogiſton, have made many obſervations and objections to theſe experiments; and when they could not gainſay the facts, they endeavoured to explain them by different ſuppoſitions. But I confeſs that I think their explanations infinitely embarraſſed and hypothetical. There has appeared ſince, long after the date of theſe experiments, a proof of a very different kind.

Meſſrs. Van Trooſtwyck and Dieman, of Haerlem, produced electric ſparks under water by the diſcharge of a ſquare foot of coated glaſs between two balls of gold. At every ſpark a ſmall bubble of air was formed between the balls, which aſcended through the water, and occupied the upper part of the tube that contained it. The air thus collecting, cauſed the ſurface of the water gradually to ſubſide. At laſt, it ſunk ſo as to be below the uppermoſt of the two gold balls. The next ſpark, therefore, was not under water, but in the air. The very firſt ſpark that was made in theſe circumſtances, exploded the whole air which had been collected. When this did not burſt the tube, (which it ſometimes did), the water immediately filled it to the very top, the whole air having vaniſhed. Here is a decompoſition, and ſubſequent recompoſition of water, which I ſee no way of gainſaying *.

* If further proof be ſtill wanted, the wonderful effects of galvaniſm ſupply them in abundance. Mr. Woolaſton alſo has greatly improved the method of the Dutch philoſophers, by availing himſelf of the well known property of fine points, by which they promote the transference of electricity; (a property happily explained by Mr. Cavendiſh, in the 61ſt volume of the Philoſophical Tranſactions). By employing a very ſmall ſhred of fine gold-leaf, all coated with ſealing-wax, except the very extremity formed by breaking it acroſs, he ſo conſtipated the ſtream by which the electric fluid is ſuppoſed to flow in or out, that a very middling machine, without coated glaſs, produces a continual decompoſition.

EDITOR.

By the help of this diſcovery of the compoſition of water, Mr. Lavoiſier eaſily explains the production of inflammable air during the ſolution of iron in diluted ſulphuric acid, which you may remember I told you was the beſt proceſs for obtaining it pure. While the ſulphuric acid diſſolves the iron, and divides it into parts inconceivably minute, it puts it into a condition for more powerfully attracting the oxygenous principle of the water. It attracts ſome of it, and thus leaves diſengaged hydrogen, which aſſumes the form of inflammable air *. Lavoiſier remarks that we do not obtain inflammable air, but ſulphur, or ſulphurous acid, when the ſulphuric acid is concentrated. It muſt be largely diluted. Here the diſſolving iron, having plenty of water to act upon, attracts oxygen more eaſily from it than from the acid. It is certain that it unites with oxygen on this occaſion, for if we ſeparate it from the acid, we find it in fact combined with oxygen, and can obtain this from it again.

Thus, you will now underſtand the opinion which at preſent prevails concerning the nature of water, and of this highly inflammable ſubſtance, and the conſequences of inflaming it.

We may now further remark with regard to inflammable air, that it is at preſent conſidered as one of the ſimple or elementary bodies in nature. I mean, however, the *baſis* of it, called the *hydrogen* by the French chemiſts; for the inflammable air itſelf, namely, *hydrogen gas*, is conſidered as a compound of that baſis, and the matter of heat. What appearance and properties that baſis would have, were it deprived of its latent heat and elaſtic form, and quite ſeparated from all other matter, we

* I do not ſee how its attraction for oxygen is increaſed. The iron is certainly, by this doctrine, combined with oxygen derived from the ſulphuric acid,—a compound of oxygen and ſulphur. How can this increaſe its attraction for oxygen already combined with hydrogen? The firſt action of the iron is generally ſuppoſed by the French chemiſts to be exerted on the water; and they ſuppoſe that the ſulphuric acid acts only on the compound already formed of iron and oxygen. This may perhaps aſſiſt, by removing the iron already ſaturated with the oxygen taken from the water; but there is ſtill a difficulty,—to be noticed afterwards. EDITOR.

cannot tell; but it is ſuppoſed to be an elementary principle in the compoſition of a great number of natural bodies; particularly, it is an ingredient in all animal and vegetable ſubſtances. The attention of chemiſts was much directed to this object by ſome moſt ingenious experiments and reaſonings of Mr. Lavoiſier and Mr. Berthollet; and it is now pretty generally received as a thing fully demonſtrated, "that nothing "is to be found in the bodies of plants and animals, except the four "kinds of gas which we have diſcovered, namely, hydrogenous, car-"bonic, oxygenous, and azotic; and a ſmall quantity of earthy and ſa-"line matter." And theſe ſubſtances, hydrogen, carbon, oxygen, and azote, are ſuppoſed to exiſt in the plant or animal in various ſtates of compoſition, forming ſolids and fluids, in which theſe ſimple ſubſtances do not exhibit their peculiar properties, by reaſon of their compoſition. The chemiſts of the new ſchool further hold, that the union by which theſe ſubſtances exiſt as ingredients in the diſtinctive ſolids and fluids of organiſed bodies, is but ſlight; ſo that it readily gives way to changes of temperature, and to the vital functions of the plant or animal; and that this is the cauſe of thoſe fermentations and corruptions which we obſerve in them all. By theſe mutual actions of the ſenſible ingredients, theſe ultimate ſimples change their partners, (ſo to ſpeak), and become ingredients of new compounds, uniting by pairs or triplets, in conſequence of a change produced in their former attractions,—a change occaſioned by a change of temperature, or by the living powers of the plant or animal.

When we maturely reflect on the ſubject, we ſee that the opinion has a great degree of probability, and that an inconceivable variety of appearances may fairly reſult from this ſeemingly very ſimple conſtitution of things. The theory here aimed at is moſt magnificent and comprehenſive, embracing almoſt all the chemical phenomena of nature; and it even promiſes ſome introduction to the knowledge of thoſe myſterious functions of vegetable and animal life, by which plants and animals aſſimilate, or convert into their own peculiar ſubſtances, the various materials which ſerve them for food and nouriſh-

ment, ſo that even air, and light, and heat, become part of their compoſition. But it is at the ſame time very evident, that the moſt ſcrupulous caution is neceſſary in all our diſquiſitions on this ſubject, and the utmoſt moderation in our theories. The combinations of pairs and triplets, in a collection of five ingredients, are ſo numerous, that it is in our power to bring out any ultimate compound that we pleaſe, by properly ſelecting the order of ſucceſſion of their mutual actions.

I ſhall give you one example of this manner of proceeding, which ſeems to meet with general approbation, and will give you a pretty clear notion of the kind of reaſoning employed in the French ſchool. This is the explanation given of the compoſition and formation of the volatile alkali. *(See Note 7. at the end of the Volume.)*

All the volatile alkali that we know is produced from animal and vegetable ſubſtances, or ſubſtances derived from theſe, by the action of heat, or by putrefaction. Yet we cannot diſcover it to be preſent in the ſubſtances from which it is thus obtained *(ex. gr.* in ſilk, animal jelly, &c.) before the action of great heat, or before putrefaction.

We have long had reaſon to believe that volatile alkali is a compound ſubſtance, and contains inflammable matter. The deflagration of nitrous ammoniac, and of all the ammoniacal ſalts with nitre, put this paſt doubt. Putrid ſteams, when copiouſly produced, are generally alkaline; they are always inflammable; and it is not till the putrefaction, accompanied by ſuch ſteams, has proceeded a certain length, that the alkaline ſmell is perceived. It becomes gradually more ſenſible and leſs fœtid.

Mr. Berthollet obſerved that the muſcular fibre, when freſh, gave out a great quantity of azotic gas, if digeſted with nitric acid; but if ſo treated when in a putrid ſtate, it gave none, but gave inflammable air and volatile alkali. He was induced by this to think that the ammonia, which appears in this proceſs of putrefaction, ariſes from a combination of the azotic gas and the inflammable air, in the inſtant of their extrication from the compounds from which they were diſ-

engaged. He ſuppoſed that ammonia is compoſed of inflammable air and azotic gas, or of the hydrogenous and azotic gaſes.

This opinion appeared to Mr. Berthollet almoſt demonſtrated, by the effect produced on volatile alkali by the muriatic acid ſurcharged with oxygen. Although the liquid alkali was perfectly cauſtic, the mixture produced a conſiderable efferveſcence. But the gas which eſcaped was not carbonic acid, but pure azotic gas: This, being a ſimple ſubſtance, muſt have exiſted in the materials. The acid contains none; it therefore made a part of the alkali. In the mean time, the acid became ordinary muriatic acid,—its redundant oxygen had diſappeared,—it had combined with the hydrogen of the alkali, and formed water.

This opinion explains, and is confirmed by many obſervations of different chemiſts before this conjecture of Berthollet; and, in the firſt place, ſome very remarkable experiments by Dr. Prieſtley, in which he ſhewed that inflammable air had the properties of other inflammable bodies, but with circumſtances that were characteriſtic. Thus, we know that minium, or red lead, is converted into lead by making it red hot, in contact with oils and other inflammable liquids and ſolids. In like manner, it is converted into lead, if heated by a burning-glaſs, when expoſed in a veſſel filled with inflammable air. In this experiment, the inſide of the veſſel is covered with dew, which trickles down the ſides, and proves to be pure water. The inflammable air is almoſt completely abſorbed.

But it is alſo converted into lead, if treated in the ſame manner, in a veſſel filled with pure cauſtic volatile alkali. But in this experiment, there is a great remainder of unabſorbed gas. Dr. Prieſtley expected to find this nearly pure vital air,—the lead having (according to his theory) abſorbed all the phlogiſton of the alkali. He was aſtoniſhed to find it, on the contrary, highly phlogiſticated; that is, nearly pure azotic gas.

Mr. Berthollet explains theſe two experiments in a very ſatisfactory manner. Minium contains (as we ſhall learn in due time) a quantity of oxygen. This, uniting with the hydrogen in the firſt experi-

ment, produces the water which Dr. Prieſtley obſerved, and the hydrogen diſappeared. But, in the ſecond experiment, the azote, which is a ſimple ſubſtance, and muſt have exiſted in ſome of the ingredients, but cannot be demonſtrated in minium carefully prepared, muſt have come from the ammonia, and muſt have been one of its ingredients. The other is, in all probability, hydrogen; for it is a ſimple ſubſtance, and it is yielded by putrid muſcle when digeſted with nitric acid; which putrid muſcle alſo yields volatile alkali. It yields volatile alkali only when it ceaſes to yield diſengaged azote, the putrefactive proceſs having combined it with the hydrogen.

This is the general theory, founded on a very few experiments indeed, but theſe abundantly ſimple. They are not, perhaps, deciſive; but this theory gathers ſtrength by attending to a number of more complex facts, and taking along with us the two diſcoveries of Mr. Cavendiſh,—the compoſition of water, and that of the nitrous acid, as propoſitions fully demonſtrated.

1. Our newſpapers inform us that the French chemiſts procured ſaltpetre for the army, by blowing alkaline gas, and even putrid ſteams, through red hot ſubſtances which readily yield oxygen. We know that ſuch ſteams yield both inflammable air and azotic gas. The laſt of theſe ſeizes part of the oxygen preſented to it, and forms nitrous acid, while another part combines with the inflammable air, and compoſes water, which dilutes the acid. It ſeems to be for ſuch reaſons that putreſcent ſubſtances are uſeful in nitre beds, and that the nitre firſt obtained is frequently nitrous ammoniac.

We often find the older chemiſts expreſſing their ſurpriſe at the ſtrong ſmell of volatile alkali from the mixture of ſubſtances which contain none. Thus, iron or copper filings, when diſſolved in ſtrong nitrous acid, often emit the ſmell of volatile alkali, inſtead of the offenſive ſmell generally emitted from this mixture. The metal may be ſuppoſed to decompoſe the water; and the hydrogen, uniting with the azote (now redundant in the nitrous gas in conſequence of the diſſolution of ſome metal by the acid) will form ammonia.

Dr. Auſtin, who had early formed the ſame opinion of volatile alkali, narrates, in the Philoſophical Tranſactions for 1788, ſeveral facts of the ſame kind. The following is one of the moſt ſimple, and is very conſtant:—Put a ſmall quantity of iron filings, very pure and clean, into a phial containing azotic gas, having previouſly wetted the filings with pure water. The gas will be quickly abſorbed, and ſigns of ammonia will appear: The ſmell becomes very diſtinct,—teſt-paper becomes green,—paper dipped in the ſolution of copper in muriatic acid, will become blue;—theſe are all marks of ammonia. All this will happen, but more ſlowly, in common air, which contains azote in abundance. The proceſs is obvious: We know that the iron decompoſes the water which wets it,—the diſengaged hydrogen combines with the azote. For the ſame reaſons, we ſmell volatile alkali in a mixture of iron filings, ſulphur, and water. It would ſeem, however, that in all theſe experiments one or both of the gaſes muſt be catched by the other in its naſcent ſtate, in the very act of its extrication. Dr. Auſtin could not combine them when already in the form of a gas. *(See Note* 8. *at the end of the Volume.)*

On the other hand, facts have frequently occurred which are beſt explained by the decompoſition of volatile alkali. Mr. Milner, by blowing akaline gas through red hot manganeſe, which yields oxygen in great abundance, produced nitrous acid, as the French did. Alſo, the muriatic acid, taken in a ſtate in which it is overcharged with oxygen, being blown through, or made to mix with alkaline gas, (ammonia) produces water and azotic gas. The oxygen ſeizes the hydrogen of the alkali, and forms water; and the azote is diſengaged. In general, when ammonia is forced to bear a red heat, in contact with ſubſtances which readily yield oxygen, we obtain azote and water. If they ſtrongly attract azote, we obtain inflammable air.

Such are the facts which ſeem to eſtabliſh Mr. Berthollet's opinion of the compoſition of volatile alkali. He imagines it to conſiſt of one part of hydrogen, and four parts (by weight) of azotic gas nearly.

The union of inflammable with vital air came in our way in con-

ſidering the effect of heat on inflammable air. Its importance has occaſioned me to take up a good deal of time with it. I now proceed to conſider how inflammable air is affected by mixture with other ſubſtances.

It has little diſpoſition to mix with pure water. It does, however, mix in a ſmall proportion, and gives it a very nauſeous ſmell. It is this that offends ſo much when water is thrown on red hot coals. In its pure gaſeous ſtate, it is by no means offenſive, although rather unpleaſant. I ſpeak of the pure hydrogen gas, obtained from iron or zinc, diſſolving in the mineral acid. This is diſtinguiſhable, by its great levity, from that obtained from vegetable and animal ſubſtances. When its weight is more than one-thirteenth of that of common air, it is impure, and has various ſmells (all bad), according to the ſources from which it was obtained, or the mixture it holds in ſolution. All of them are conſiderably heavier than the one now under conſideration. They generally emit a brighter flame. The inflammable air from marſhes is uſually called the *heavy inflammable air*. Another produced from charcoal has ſome remarkable properties, particularly its operation on living animals who reſpire it. It is called *hydrocarbonat*, and will be noticed very ſoon. It is reaſonable to doubt whether theſe inflammable gaſes have any thing in common with hydrogen beſides their inflammability. Yet all compoſe water by deflagration with oxygen. Therefore they contain ſome common ſubſtance.

Hydrogenous gas loſes much of its inflammability by frequent agitation with water, and gives it a bad ſmell.

It has little action on the alkaline ſalts. Mr. Lavoiſier was once diſpoſed to conſider it as the alkaline principle; and I obſerve that Chaptal, and others, have ſtill a leaning to this opinion. This gas combined with quicklime is ſuppoſed to form potaſh, and ſoda when mixed with magneſia *. But I ſee very little to ſupport this notion.

* See a letter from Van Mons in the *Annales de Chymie*, of which an extract is given in *Nicholſon's Philoſophical Journal*, IV. 334. EDITOR.

Its action on the acid ſalts is much more diſtinct. If a little ſtrong ſulphuric acid be heated in the bottom of a very narrow and tall glaſs, which ſwells out at the other end like a pear,—and if, in this ſtate, inflammable air be blown through it by a long pipe from a bladder, they unite very readily; the hydrogen from the gas unites with the oxygen of the acid,—and they form water. The acid, deprived of its due proportion of oxygen, becomes redundant in ſulphur, which is manifeſt by its ſuffocating fumes; and even ſulphur in powder will ſometimes collect in the wide part of the glaſs. When the acid is concentrated as much as poſſible, and made to boil before the inflammable air paſs through it, it acts in another way. Inſtead of abſtracting the oxygen, and combining with it, it combines with ſome of the ſulphur, and comes off in form of an abominably fœtid gas, which will be conſidered afterwards by the name of *hepatic gas*, or *hydro-ſulphuret*, only noticing at preſent that it preſerves in ſome meaſure the chemical relations of an acid. When paſſed through an alkaline ſolution, it forms a ſort of neutral ſalt, having a diſguſting fœtor and taſte. But,

Nitric acid alſo abſorbs this gas very readily. We can ſee at once what muſt be the effect of an acid which yields oxygen ſo readily,—it becomes ruddy and fuming, becauſe water is formed of part of its oxygen, and the nitrogen or azote is now predominant.

This mixture gives me the firſt opportunity of confirming the diſcovery of the compoſition of nitrous acid by Mr. Cavendiſh, which I mentioned when giving you an account of the gaſes diſcovered by different chemiſts, after the publication of my diſſertation on fixed air and quicklime. I conſidered it as abundantly proved by that experiment of Mr. Cavendiſh. But it has been proved ſince that time by many experiments, in which the two ingredients oxygen and azote are ſeparated. None exhibit this more clearly than the mixture of nitrous acid, or nitrous ſalts, with inflammable ſubſtances. Inflammable air is the firſt and moſt ſimple of them, at leaſt in its chemical relations.

When a long continued ſtream of inflammable air is made to paſs through nitric acid, we obtain (in a pneumatic apparatus) the gas which Prieſtley calls *nitrous air*, which is colourleſs at laſt, though ruddy in the beginning, and has no acidity, nor changes the colour of teſt paper, and is ſcarcely abſorbed by water. This gas, when mixed with vital air, (oxygenous gas), collapſes with it into nitrous acid. Here then is a proof that vital air is one of its component parts. The inflammable air had united with a part of the oxygen that is more eaſily detached from the perfect acid, and the gas which came from it is therefore deficient in it; ſo deficient as not to be acid. But when oxygen is preſented to it, it is combined, and we have again nitrous acid. In the mean time, the nitric or perfect acid is become fuming, and alſo weaker, or diluted, by the water that is formed by the inflammable and vital air.

It is to be particularly remarked in this experiment, that although the gas produced is clear, and nearly colourleſs, and vital air is the ſame, yet theſe two, on mixing, form, for a few ſeconds, a thick ruddy cloud; and a very ſenſible heat is produced by their condenſation into nitrous acid *.

If the experiment be made with common air, in the place of oxygenous gas, we ſtill produce nitrous acid, and have the ruddy cloud; but the two airs do not vaniſh, but leave a conſiderable reſiduum of azotic gas. The reaſon of this is now obvious. The nitrous air combines only with the oxygen of the atmoſpheric air, and leaves the azote. It was no part of the nitric acid employed in the experiment. We now alſo ſee the cauſe or origin of thoſe red fumes which appear in moſt experiments with the nitrous acid. They are formed during the combination of nitrous air with the vital portion of common air.

This experiment is therefore inſtructive; but it is extremely

* Theſe ruddy fumes are moſt evidently veſicular, and ſome of the veſicles very large. EDITOR.

tedious, becauſe the quantity of matter in a reaſonable bulk of inflammable air is ſo very minute. We ſhall have much better examples as we proceed.

Its relations to the other acids, to the compound ſalts, and to the earths, have been but little examined as yet. We are now to be occupied with the other inflammable ſubſtances; and ſhall conſider the relation of it to each. Some are very remakable.

II.—PHOSPHORUS.

The next ſort of inflammable ſubſtances we propoſed to deſcribe are thoſe named PHOSPHORI. The principal ſpecies of theſe is commonly named the PHOSPHORUS OF URINE, on account of its having been prepared formerly from urine.

When pure and newly prepared, it is ſemitranſparent; and by its degree of coheſion bears ſome reſemblance to white bees wax. It makes nearly the ſame reſiſtance to a knife in cutting it; and it melts with a heat even inferior to that of melting wax, coinciding rather with the heat of the human body.

It may be melted with this heat ſafely, if immerſed in water, and covered by it from the contact of air; or even without water, provided the glaſs veſſel containing it be of a ſmall ſize, and cloſed up, to prevent the renewal of the air in it.

In a ſmall retort, with a ſuitable receiver cloſely luted to it, this phoſphorus can both be melted, and by an increaſe of the heat to the loweſt degree of ignition, can be converted into vapour, and thus made to paſs over into the receiver, which being kept cool, the phoſphorus quickly congeals in it, and is in the ſame ſtate as before. It is ſometimes ſubjected to this ſort of diſtillation in order to purify it.

But, in all ſuch operations with it, we muſt be very careful that no freſh air be admitted into the veſſels until they be perfectly cold

again, and, even then, the moment the receiver is ſeparated from the retort, it ought to be filled with cold water.

This precaution is neceſſary, on account of the extraordinary propenſity of this ſubſtance to be inflamed by the action of freſh air, eſpecially if it be in the leaſt warm, or expoſed to the air, with an extenſive ſurface of communication with it. And, when it takes fire, it burns with amazing rapidity and violence. It is therefore proper to be cautious in handling it, as the warmth of the fingers may ſet it on fire.

The low degree of heat at which it takes fire ſhews the extraordinary inflammability of this ſubſtance, and is the foundation of many of its remarkable properties, and of ſome of the tricks that are played with it, ſuch as ſetting paper on fire by rubbing the paper *. We may kindle tow, which conceals a little bit of it, and is looſely wrapped round a phial, by pouring hot water into the phial, or by mixing in it two cold liquors which grow hot by mixing. Another trick is to light a candle by touching a glaſs of cold water. The glaſs has a minute bit of phoſphorus ſtuck on its edge. The ſhowman pours cold water into it, blows out the candle, and while the wick is ſtill hot, he touches the phoſphorus with it, which inſtantly takes fire. With this phoſphorus alſo are made what are called phoſphoric matches. Theſe philoſophical toys are ſlender wax tapers, having an atom of phoſphorus at the end; and each muſt be kept in a glaſs tube hermetically ſealed. It is warmed by putting that end into the mouth,—then broken, and the taper ſuddenly

* This is done by previouſly drawing a ſtrong line with a piece of phoſphorus on a piece of ſtiff and rough paper, ſuch as cartridge paper, laid upon ſome very cold body during the friction. The warmth of the fingers being ſufficient to ſet phoſphorus on fire while it is ſo hard rubbed, it muſt be wrapped two or three times round in a piece of wet paper. In order to ſhew the trick, the paper is folded upon the ſtroke, and briſkly rubbed very hard one part upon the other. The phoſphorus that was left upon it is generally ſufficient to ſet it on fire.

drawn out. It generally takes fire. They are coſtly, offenſive by their vile ſmell, and very childiſh.

During the rapid inflammation of the phoſphorus, it is quickly changed into a ſaline ſubſtance, which is no longer inflammable in the ſame degree, and which is thrown out of the flame or burning vapour in the form of a thick white ſmoke. A part of this ſmoke is diſperſed in the air, and unavoidably loſt; but a conſiderable part of it is immediately condenſed on the ſurface of the veſſel, in the form of a ſaline cruſt, which has a ſtrong attraction for the humidity of the air, and is very ſoon liquefied by it, forming with it an acid liquor.

Although this acid matter, when firſt produced, is no longer inflammable in the ſame degree as the phoſphorus, it ſtill retains a ſmall degree of inflammability. This we learn when we expoſe it to a ſtronger heat, ſuch as that of red hot iron. Then, after glowing a little, it becomes, at laſt, a white or tranſparent ſaline ſubſtance, which has loſt all remainder of inflammability, and is a perfect acid.

The properties of this acid were firſt inveſtigated by Mr. Margraaf of Berlin, and publiſhed in the Tranſactions of the Royal Academy there, and ſince, in his *Opuſcula*, which have been tranſlated from the German into the French language. The compounds which it forms with different ſubſtances are alſo deſcribed by M. Fourcroy.

Mr. Margraaf made it return to the ſtate of phoſphorus, by mixing it well with charcoal powder, and expoſing this mixture in earthen retorts to a violent heat in the way of diſtillation, with the proper precautions for preventing the phoſphorus from taking fire in the receivers.

His opinion of the converſion of the phoſphorus into an acid by inflammation was the ſame with that of other chemiſts at that time; namely, that it happened in conſequence of abſtracting the phlogiſton; and yet he particularly remarks, that the quantity of the

acid which he collected by burning it gradually, or by ſmall bits in ſucceſſion, greatly exceeded the quantity of the phoſphorus.

This fact has been more exactly aſcertained ſince that time by the experiments of Mr. Lavoiſier, and others. And many inſtructive diſcoveries have been made by means of the inflammation of phoſphorus, and its converſion into an acid. It is peculiarly fitted for being uſeful in inveſtigations relating to combuſtion. Sulphur and inflammable air are equally ſimple and effective. But the compounds which they make by inflammation are ſo volatile, or offenſive, or troubleſome, that they are almoſt unmanageable. Here it is quite otherwiſe. This pointed it out to Scheele and Lavoiſier as the fitteſt ſubſtance for aſcertaining the change produced on air by combuſtion. No volatile matter from the phoſphorus will in any way taint it. It is now well known, that when it is burned in a limited quantity of atmoſpherical air, the vital part of the air, or the oxygen gas, is expended and diſappears, without any formation of carbonic acid. And when burned in pure oxygen gas, it burns with amazing brightneſs and violence, and the whole of the gas is abſorbed and diſappears.

The burning of phoſphorus in oxygen gas was firſt tried by Mr. Scheele; but the ſame experiment was afterwards repeated by Mr. Lavoiſier, with larger quantities of the phoſphorus, and with the moſt careful attention to every circumſtance which could affect the concluſion to be drawn from it.

Scheele put his bit of phoſphorus into a phial filled with oxygen gas, cloſed the mouth of the phial with a cork, and then warming the phial, he thus kindled the phoſphorus. When the inflammation was finiſhed, and the phial was cool again, he plunged it into water, and drew out the cork under water. The water was ſuddenly preſſed into it by the atmoſphere, and filled the phial perfectly full, or very near it. He therefore concluded that the oxygen gas had united with the phlogiſton of the phoſphorus, ſo as to form with it heat and light, which had paſſed through the glaſs.

But Mr. Lavoiſier, performing a ſimilar experiment, took the precaution to weigh the glaſs with what it contained immediately before the inflammation of the phoſphorus. Weighing it again, after the inflammation, and before it was opened, he found it was preciſely of the ſame weight. Afterwards, examining as exactly as poſſible the weight of the acid into which the phoſphorus was changed, he found that it exceeded the weight of the phoſphorus conſumed, by a quantity exactly equal to the weight of the gas which had diſappeared. It was therefore evident that the gas was now changed, by the loſs of its latent heat, into a denſe matter, which made up the greater part of the weight of the acid. One part of phoſphorus abſorbs in this way a little more than $1\frac{1}{2}$ parts, by weight of the oxygen gas. The acid is made up of the phoſphorus and oxygen, in the proportion of 100 to 154 *.

The change of phoſphorus into an acid is, therefore, frequently named the OXYDATION of phoſphorus; and other ſimilar changes of other inflammable ſubſtances are alſo called OXYDATIONS †.

* This experiment muſt be conſidered as one of the moſt convincing proofs of the doctrine of the French chemiſts. Whatever notion we have of the phoſphoric acid, it is plain that the phoſphorus itſelf enters into its compoſition; for the phoſphorus diſappears, and we have the acid in its ſtead. It can never be ſaid, therefore, that phoſphorus conſiſts of the phoſphoric acid and phlogiſton; for phoſphoric acid conſiſts of phoſphorus, and ſomething beſides: Theſe are irreconcilable. EDITOR.

† It is rather an unlucky term, choſen in the heat of diſcovery, and before Mr. Cavendiſh had diſcovered the compoſition of water. Had this been known, it is not likely that a perſon of Mr. Lavoiſier's general knowledge and good ſenſe would have included the formation of water in the liſt of acidifications. Moſt of his followers were leſs ſenſible of the violence done to common language. Perhaps they even liked a diction which will cauſe the uninitiated to ſtare. We ſee this very plainly in the phraſeology of ſome of them, who are fond of uſing the term combuſtion in caſes where a plain man can ſee nothing like it. What he would call combuſtion they call oxydation; and what he would call oxydation they call combuſtion. The formation of water is an *oxydation of hydrogen*; but the formation of nitrous acid is the *combuſtion of azote*. There is little ſcience in this, but abundance of vanity. EDITOR.

Since theſe diſcoveries were made, Mr. Pelletier, another French chemiſt, who has diſtinguiſhed himſelf by many inſtructive experiments relating to phoſphorus and the proceſs for preparing it, contrived a proceſs for oxydating phoſphorus, which appears to be very effectual, and very well fitted for preventing the loſs of any part of the acid.

He melts the phoſphorus under water, in a cylindrical glaſs veſſel, and then throws into it oxygen gas, by very ſmall quantities at a time, through a glaſs tube, connected with a bladder, containing the gas. Every little addition of the oxygen gas kindles that part of the phoſphorus with which it comes in contact, and is abſorbed by it. That part of the phoſphorus is thus changed into acid, and diſſolved by the water: And thus the whole of it can be thus oxydated, or changed into acid, which is diſſolved by the water.

Another proceſs or experiment, founded on the ſame diſcoveries, may alſo be mentioned here. It is an experiment by which we learn the proportion of oxygen gas contained in atmoſpherical air. *The eudiometer of phoſphorus*, or method for learning exactly, by the uſe of phoſphorus, the proportion of oxygen gas contained in atmoſpherical air, contrived by Seguin and Lavoiſier. *Annales de Chymie, tom.* ix. *p.* 301.

Get a glaſs tube about one inch in diameter, cloſed above and widened below, and about ſeven or eight inches long. Fill it with quickſilver, and invert it into a ciſtern of the ſame fluid. Throw up or introduce into it a little bit of phoſphorus, and approach a burning coal to the upper end of the tube, to warm and melt the phoſphorus by blowing on the coal. Then, having meaſured a proper quantity of the air to be tried, throw it up by ſmall portions at once, each of which will cauſe the phoſphorus to burn, and will thus conſume or ſaturate ſome of it, and in ſo doing will be ſaturated, and changed into acid, in as far as it conſiſts of oxygenous gas. When it is all thrown up, warm the tube again, to be ſure that the oxygen gas ſhall be completely ex-

pended or ſaturated. Laſtly, let it cool, and transfer the air into another tube which is graduated for meaſuring exactly the bulk of the remaining air. This will ſhew the quantity of the oxygen gas which it originally contained. A glaſs funnel, having the extremity of its tube cloſed up, may ſerve very well in place of the above apparatus.

Theſe are the moſt remarkable particulars of the properties of phoſphorus with reſpect to heat, and the manner in which it is inflamed and changed into phoſphoric acid.

It has alſo a quality, upon which have been founded many of the curious experiments and ſurpriſing tricks that have been performed with it. This quality of it appears when it is expoſed to the air in an extended ſurface, but in degrees of heat inferior to that neceſſary for its bright inflammation. It then emits a pale light, viſible in the dark only. We do this very effectually by drawing lines with phoſphorus on ſtrong white paper.

When we view the paper in day light, the light of the phoſphorus is not perceived, in conſequence of its weakneſs, but a white ſmoke is ſeen to ariſe from it. A ſmall ſolid maſs of phoſphorus continues to emit this pale light and ſmoke a ſurpriſingly long time. Mr. Boyle relates that a bit of phoſphorus, weighing only three grains, continued to emit this weak light fifteen days and nights before it was exhauſted.

From the conſequences obſerved, when a bit of the phoſphorus is thus expoſed on a plate of glaſs a little inclined, we find reaſon to be ſatisfied, that this luminous ſtate of it is only a ſtate of very ſlow inflammation. It is gradually converted into an acid, which attracting humidity from the air, forms an acid liquor, much the ſame with that formed by the bright and violent inflammation of the phoſphorus; only that it is not quite ſo perfect an acid. It is ſtill ſomewhat deficient of the proper quantity of oxygen: This trickles down along the glaſs, and may be thus collected.

One of the proceſſes for converting phoſphorus into an acid is

founded on this property. The phoſphorus, formed into ſmall cylindrical pieces, is put into a glaſs funnel, the throat of which is ſlightly ſtopped with a pebble or a bit of glaſs, to prevent the deſcent of the phoſphorus into the pipe. A phial is then placed under the funnel, and the whole apparatus ſet in a moderately cool place. Thus the acid of the phoſphorus, in proportion as it is formed, drops into the phial. But we muſt take care that the place in which the apparatus ſtands be ſufficiently cool. A ſmall increaſe of the heat of the air has great effect in accelerating the proceſs; and if it be much accelerated, the phoſphorus becomes warm by the very oxydation, and there is danger of its taking fire, and burning with violence. Scheele diſcovered that even the weakeſt lumination of the phoſphorus is attended with the production of ſome perceptible heat, diſcoverable by a thermometer. But when the proceſs I ſpeak of is rightly conducted, this heat being weak and ſlowly produced, it is carried off by the ſurrounding air, ſo that it never is accumulated in ſuch quantity as to diſpoſe the phoſphorus to be rapidly inflamed.

We come now to conſider phoſphorus in mixture with other bodies. Being a ſubſtance of recent diſcovery, its chemical relations have not yet been thoroughly examined. Many of thoſe we know are very remarkable. Mr. Margraaf, to whom we are indebted for the knowledge of the chemical nature of this ſubſtance, has made theſe combinations with his uſual judgment and accuracy.

A drachm of phoſphorus was diſtilled by him with an ounce and a half of ſulphuric acid, giving at laſt a violent heat. A few grains of phoſphorus remained, mixed with a ſpongy white maſs, which deliqueſced in the air. The liquor which diſtilled was thickiſh, and a little milky. Both liquors contained a mixture of ſulphuric and phoſphoric acids.

A drachm of phoſphorus was diſtilled with an ounce of ſtrong nitric acid. As ſoon as it was dropped into the acid, blood red fumes were diſengaged, which made him fit on the receiver in a hurry. The ſolu-

tion went on with great vehemence and heat, and in a ſhort time the greateſt part of the nitrous acid came over, without applying any fire to the retort; at laſt the phoſphorus yet remaining took fire, and burſt the retort with great noiſe.

The union of the oxygen and azote in the nitric acid is ſo weak, that ſcarcely any body which attracts oxygen can be preſented to the acid which will not overcome their union and decompoſe the acid. The azote, or rather nitrous gas, eſcapes and produces thoſe red fumes, by uniting with the atmoſpheric air. The latent heat of the oxygen, as it is contained in the nitric acid, greatly exceeding what is neceſſary for the acid of phoſphorus, emerges and produces heat enough to inflame the remaining phoſphorus.

But, by another way of conducting the proceſs, it is very manageable. Put ſtrong nitric acid into a tubulated retort fitted with a receiver. Have ready a quantity of phoſphorus cut into very ſmall pieces; drop in one, and immediately ſtop the hole. The phoſphorus will diſſolve very quickly, and will produce heat. When all is cool, drop in another bit, and continue this till the laſt bit diſſolves and ſeems to ſaturate the acid. Now apply heat, and the nitric acid will diſtil over in fiery fumes, and leave nearly pure phoſphoric acid in the retort.

This mixture alſo gives us a pretty enough phenomenon. Put about half an ounce of ſtrong nitric acid into a ſmall and thin flaſk with a narrow mouth. Drop in a bit of phoſphorus like a large pea. There is an effervеſcence, or rather an exploſion, during which a ſlender column of flame is darted out of the glaſs along with the vapours and drops of acid. Care muſt be taken ſo to regulate the quantity to the ſize of the orifice, that the veſſel do not burſt, and to have it of ſuch a ſhape that few drops of acid may come out.

This is the next opportunity given us for examining the compoſition of nitrous acid; and it is incomparably better than the laſt with inflammable air. Accordingly, all the phenomena are the ſame in kind, but

much more remarkable. The production of the phoſphoric acid, in the ſame quantity preciſely as if it had been produced by inflaming the phoſphorus, ſhews evidently that oxygen conſtitutes a great portion of nitric acid. The gas which eſcapes is the ſame as when inflammable air is employed, provided that the combination be ſlowly effected. If rapidly, much phoſphorus is volatilized, and taints the gas, ſometimes even making it inflammable. The fumes are blood red, while they mix with common air or with oxygen; and nitrous acid is produced by the union. If all acceſs of air be prevented, the gas is colourleſs, and without acidity. By comparing the gain to the phoſphorus, with the oxygen neceſſary for forming nitric acid with the gas, Lavoiſier found that the proportion of oxygen and azote in the gas, is that of 68 to 32 nearly. It requires about 24 parts (in bulk) of common air to ſaturate 11 parts of this gas, and form with it nitrous acid. In this mixture, the whole nitrous gas diſappears, and a fourth part of the common air, ſo that 35 cubic inches, after mixture, will only occupy 18 inches. This is azotic gas.

That the red vapours are true nitrous acid, appears from an experiment of Dr. Prieſtley. Hang in the glaſs a piece of ſal ammoniac. When the red fumes are over, a ſnowy powder ſettles all over the veſſel, which is imperfect nitrous ammoniac.

The nitrous gas may be decompoſed, and the compoſition of nitrous acid completely demonſtrated, by filling a jar with nitrous gas, and putting into it a quantity of *hepar ſulphuris*. This will immediately attract the oxygen remaining in the gas, and leave the other ingredient alone. This is found, by this experiment, to be pure azotic gas.

We may ſurely now aſſume the compoſition of the nitrous acid as a thing as firmly eſtabliſhed as any doctrine in chemiſtry. You will recollect, that, in order to anſwer an immediate purpoſe, I mentioned the precious experiment of Mr. Cavendiſh, in which he found, that when ſeven parts of vital air were deflagrated with three of phlogiſticated air, or azotic gas, the whole collapſed into pure nitrous acid.

But I did not at that time aſſume this conſtitution of the acid as a fixed point, becauſe I was not then in a condition to ſhew you how the acid might be ſeparated or reſolved into thoſe its conſtituent parts. I was unable to do this, becauſe you were unacquainted with the ſubſtances whoſe properties and manner of action were to operate this decompoſition. Enough of theſe have now occurred; and I have given you moſt diſtinct examples of the fact. More will yet occur as we proceed; and ſome of them perhaps ſtill more perſpicuous. But we have enough; and it will be agreeable now to meet with the others, as phenomena which are explained by this principle now in our poſſeſſion.

The muriatic acid did not appear to Mr. Margraaf to act at all on the phoſphorus, which did not diſſolve. At the end, indeed, of the diſtillation, the phoſphorus alſo came over, but without any remarkable change.

The pure or cauſtic fixed alkalis may be combined with phoſphorus, or can be made to diſſolve it, as they diſſolve ſulphur, and indeed all the inflammable ſubſtances in the humid way. In conſequence of this combination, an inflammable gas, extremely fœtid, ſmelling like rotten fiſh, is produced, which takes fire the moment it comes in contact with atmoſpherical air; and which therefore expoſes the veſſels to the riſk of being burſt by its exploſions.

This gas is undoubtedly produced from a ſmall portion of the water decompounded by the diſſolved phoſphorus. It is the hydrogen in its form of gas; and as faſt as it is produced, it diſſolves and volatilizes a ſmall portion of the phoſphorus itſelf, and from this receives the quality of ſpontaneous inflammability *. This ſmall portion of

* Is the ſeries of operations here ſtated very ſatisfactorily eſtabliſhed? I cannot help conſidering this experiment, and thoſe which are analogous to it in the treatment of ſulphur with alkaline ſubſtances, as examples of that gratuitous employment of the decompoſition of water, which the followers of Lavoiſier indulge in with ſo little circumſpection or moderation. All depends on the *order* in which the different actions ſucceed

the phoſphorus, however, is very ſlightly united with the hydrogen, for it is depoſited or ſeparated, if the gas be kept for ſome time confined with water. It gradually depoſits the phoſphorus on the ſides of the veſſel, loſes its ſpontaneous inflammability, and is changed into common inflammable air or hydrogen. The ſame gas is produced by quicklime. *(See Note 9. at the end of the Volume.)*

By theſe experiments, you will perceive that phoſphorus is one of the moſt eaſily inflammable bodies that we know; that it has a ſtrong propenſity to take fire, and to be inflamed,—or, in other words, that it has a ſtrong attraction for oxygen. A very ingenious and inſtructive experiment has lately been founded on this ſtrong attraction, or has been contrived in conſequence of it. It has been a great deſideratum among the chemiſts to decompound the carbonic acid; that is, to contrive ſome way by which the carbone or coal may be ſeparated from the oxygenous gas or vital air, which is now held to be its other ingredient. This has been attempted with very flattering appearances of ſucceſs by Mr. Smithſon Tenant. You have an account of it in the Philoſophical Tranſactions, vol. 81. part ii. I ſhall give you a brief account of it.

Mr. Tenant put a ſmall bit of phoſphorus into a glaſs tube that was ſhut at one end, and then put over it marble reduced to a fine powder. He ſhut the other end, but looſely, that the common air expanded by heat, might eſcape, and yet ſo that the free circulation of air, which might kindle the phoſphorus, ſhould not take place. He heated this apparatus red hot for a few minutes. When all was cold, he broke the tube, and found therein a black powder, which conſiſted of coal, phoſphorated lime, and phoſphorus mixed with quicklime.

each other. I think that phoſphorus and ſulphur, and perhaps charcoal, afford a probable opportunity of ſettling the point, by means of a previous determination of their ſimple affinities. This is not in our power, perhaps, in the more complicated ſubſtances of animals and vegetables.

EDITOR.

When the phoſphorated lime was ſeparated by ſolution in an acid, and filtration, and the phoſphorus by ſublimation, the coaly matter that remained did not appear to differ from vegetable coal in any reſpect. Mr. Tenant explains the experiment by ſaying that the coal is ſeparated from the oxygen, although it has a ſtronger attraction for it than the phoſphorus has, in conſequence of the ſum of the attractions of the phoſphorus for oxygen, and the phoſphoric acid for quicklime.

Dr. Pearſon obſerving that the compounds of phoſphoric acid and the fixed alkalis could not be made to yield phoſphorus by treating them in contact with charcoal in a red heat, while the calcareous phoſphat yields it with great readineſs, thought that the foſſil alkali would be a better intermedium than calcareous earth, for operating the decompoſition effected by Mr. Tenant. He therefore employed, with perfect ſucceſs, a mixture of two parts of phoſphorus, and eight of carbonat of ſoda, cleared of its water of cryſtallization. The proceſs was ſimilar to Mr. Tenant's, and very eaſy. The rationale of theſe proceſſes is by no means obvious; but the production of carbone, and this in due quantity, completes the theory of carbonic acid. A letter of Dr. Pearſon to Haſſenfratz, and ſome obſervations by Fourcroy, which accompany it in the 18th volume of the *Annales de Chymie*, deſerve peruſal.

Phoſphorus will alſo combine, though looſely, with the cauſtic volatile alkali, and produces a gas with an abominable ſmell. This gas alſo takes fire in the air, and, which is remarkable, depoſits the greateſt part of the phoſphorus in the flaſh. Indeed, in all theſe gaſes, containing phoſphorus volatilized by hydrogen, the union ſeems exceedingly ſlight. They all decompoſe by long keeping, even in corked phials. Weſtrumb ſays that they depoſit the phoſphorus, even in phials hermetically ſealed. That the phoſphorus is not inflamed in theſe experiments, but depoſited, appears ſingular at firſt view, ſeeing that it is ſo very inflammable. But when we conſider the extreme

rarity of the gas, and reflect that the inflammation even of this rare gas, which takes place by the mere contact of air, is probably the low inflammation, in which phoſphorus itſelf only ſhines without ordinary combuſtion, we ſhall be ſenſible that the complete inflammation of the phoſphorus is not to be expected.

Theſe are ſome of the moſt remarkable qualities and relations of this inflammable ſubſtance. It is alſo capable of being combined with ſome of the other inflammables *, and with the metals; and forms ſingular compounds, which ſhall be noticed hereafter.

The acid which it affords is alſo now become one of the important objects of chemiſtry. It is fixed and vitrifiable. With the foſſil alkali it forms a ſalt, now uſed in medicine, and recommended by Dr. Pearſon by the name of SODA PHOSPHORATA. A proceſs for preparing this neutral ſalt is given in a new edition of the Edinburgh Pharmacopœia †.

* Indeed all the inflammable ſubſtances are ſuſceptible of a perfect admixture; and this has, in many caſes, ſome appearance of a chemical combination,—the compounds having certain general properties which do not belong to the ingredients, at leaſt in the ſame degree. They are, in general, more fuſible, volatile, and inflammable, than ſhould be expected from the ingredients: And they are more diſpoſed to union with another inflammable ſubſtance. EDITOR.

† *Proceſs for Soda Phoſphorata, communicated by Dr. Pearſon.*

Take bone aſhes: Thoſe to be had at the hartſhorn manufactures are commonly uſed, and ground to a coarſe powder, in the ſtate they are in for manure, and as ſold for about a ſhilling a buſhel—ten pounds.

Pour on them, in an earthen, or iron pan, oil of vitriol, of ſpecific gravity about 1800—ſix pounds.

Stir the mixture well, and add to it gradually rain or river water—nine pounds.

Stir the whole well together, and ſet the mixture to digeſt in a ſand heat of about 130°, for two or three days; then add to this mixture nine pounds more of very hot water, and pour it on a filtre of coarſe linen cloth, upon which pour boiling water till it paſſes through with little acid taſte. Let the filtrated liquors, all mixed together, ſtand for the ſediment to fall; decant the clear liquor, and evaporate to about nine pints.

When the acid is completely freed from phoſphorus, and may therefore have the diſtinctive name PHOSPHORIC ACID, it forms with the alkalis, ſalts, which cryſtallize with great difficulty. But, when it retains ſome phoſphoreſcence and volatility, in which ſtate we may call it PHOSPHOROUS ACID, theſe compounds cryſtallize very well.

With calcareous earth it forms a ſubſtance inſoluble in water, reſembling, in all reſpects, the earth of bones.

Filtrate, to ſeparate the ſelenite precipitated in boiling, and evaporate again to ſeven pints; cool the liquor, and ſeparate more ſelenite. Heat the liquor in an earthen veſſel, and add pure cryſtallized foſſil alkali, diſſolved in 1½ its weight of water, until the effervescence ceaſes. Filtre the ſaline liquor hot, into a ſhallow veſſel, and let it cryſtallize three or four days. Decant the remaining liquor from the cryſtals; and if it be acid, neutraliſe it again with the ſolution of foſſil alkali, and evaporate again and cryſtallize; repeating theſe operations, until a liquor remain which will not give any more cryſtals, either by evaporation or addition of more alkali.

Shorter Proceſs, but with more waſte of phoſphoric acid.

Add as much water to a mixture of ſulphuric acid and bone aſhes as will reduce it to a thin paſte, which muſt be put into a coarſe thick hempen bag, tied up cloſe at the mouth. Then preſs and moiſten it with water repeatedly, until the whole, or greateſt part of the acid liquor is extracted. The turbid acid liquor muſt be purified from the ſelenite, by decantation and filtration; and if the quantity of this liquor be more than ſix pints, reduce it to that quantity by evaporation, and ſaturate, as before deſcribed, with a ſolution of foſſil alkali.

The quantity of phoſphorated ſoda ſhould be at leaſt equal to the weight of the alkali, and about five-ſixths of that of the bone aſhes; ſo that the above quantities ſhould yield above 8½ pounds of the ſalt.

This ſalt is liable to be contaminated with Glauber's ſalt, or ſuperabundant alkali, which are diſtinguiſhable in it by the taſte. The taſte of pure ſoda phoſphorata is a ſlight taſte of marine ſalt. The bone aſhes ſometimes contain more, ſometimes leſs acid, and the foſſil alkali is often impure.

The ſureſt way to ſucceed, is to be careful that the ſulphuric acid be rather too little for decompounding the whole of the bone aſhes, than that there ſhould be too much of it. In the above proceſs this is attended to.

Origin and Preparation of Phoſphorus.

The firſt proceſs by which the phoſphorus was obtained in its pure ſtate appears to have been an accidental diſcovery in 1669, (*Leibnitz de Invent. Phoſph. Miſcell. Berol.* 1.) by Brandt, a merchant in Hamburg, who was employed in experiments on urine, in the hopes of making gold; and it remained in his hands, or in the hands of a few others, who acquired the knowledge of it, but concealed it from the public for a long time after. It was brought to England by a Dr. Kraft. At laſt ſome hints relating to it were publiſhed in the Philoſophical Tranſactions, No. 196, by Mr. Boyle, who had practiſed Kraft's proceſs with ſome degree of ſucceſs. Meantime, Kunkel, a chemiſt in Dreſden, by dint of labour, diſcovered an effectual proceſs, which he publiſhed, and claimed the invention. A full deſcription of a better proceſs appeared afterwards in the Memoirs of the Royal Academy of Sciences at Paris for the year 1737, in conſequence of the purchaſe of the ſecret from a chemiſt who was poſſeſſed of it. All this is detailed very diſtinctly by Mr. Macquer, in his Dictionary of Chemiſtry. The urine was evaporated to a dry extract or coaly matter; then ſome of the ſalts were ſeparated from this extract by water; and the remaining matter was diſtilled with a violent heat in earthen retorts.

Although ſome phoſphorus may be produced by this proceſs, it is far from being a good one. Some parts of it are actually very detrimental, or diminiſh the quantity of phoſphorus which might be obtained from the materials; and the proceſs is exceedingly troubleſome and hazardous. The beſt management of the proceſs, and the manner in which the phoſphorus is actually produced by it, were never underſtood until Mr. Margraaf applied himſelf to the ſtudy of it, and publiſhed his experiments in the Berlin Tranſactions. By them it appears that the production of phoſphorus from

urine depends upon a ſalt contained in the urine, and which had been obſerved in it before, but not ſufficiently examined. Dr. Boerhaave takes notice of it, and calls it the eſſential ſalt of urine. Mr. Margraaf collected a quantity of this ſalt and examined it. He found it ammoniacal, or containing a volatile alkali in its compoſition. It is a mixed neutral, compoſed of a peculiar acid, combined partly with each of the fixed alkalis, and partly with ammonia. With charcoal duſt this ſalt gave a larger yield of phoſphorus than ever had been got from any other materials. And the remains of the urine from which this ſalt had been extracted gave hardly any ſenſible quantity of phoſphorus. Mr. Margraaf alſo ſhewed, by a train of experiments, that the phoſphorus is changed by inflammation into an acid, now named the phoſphoric acid; which acid can again be changed into phoſphorus. This cleared up the whole matter, and gave reaſon to be aſſured that the ſalt juſt now mentioned contains this very acid.

In conſequence of theſe diſcoveries, Mr. Margraaf contrived ſome improvements of the proceſs for preparing phoſphorus from urine; by which improvements the operation was facilitated, and the yield of phoſphorus much increaſed.

This proceſs of Margraaf's continued to be the beſt, until Mr. Scheele of Sweden, in company with Mr. Gahn, another eminent chemiſt, taught us one ſtill better. The two gentlemen juſt mentioned have ſaved us the trouble of evaporating urine, by diſcovering that the acid of phoſphorus is contained in the bones of animals; and when combined with the calcareous earth, forms their baſis, or their moſt ſolid and fixed matter,—that is, the white earthy-like matter which remains of them after all their inflammable matter is conſumed; in ſhort, what is uſually called *the earth of bones*. The proceſs theſe gentlemen propoſed for extracting the acid from this matter was a little complicated. A more ſimple one has been diſcovered ſince that time. We need only to mix with the bone aſhes ſome ſulphuric

acid and water, &c.—*(Vide firſt part of the proceſs for ſoda phoſphorata, in the Pharmacopœia Edinenſis).*

But the phoſphoric acid may be extracted by other proceſſes, as 1*mo*, By applying the mild volatile alkali, or carbonat of ammonia, to the bone aſh reduced to fine powder. (N. B. The double exchange will probably happen beſt in a cold place).

2*do*, By applying ſulphat of ammonia, diſſolved in water, to the bone aſhes.

Since theſe diſcoveries have been made, the production of this inflammable ſubſtance is a much eaſier operation than it was formerly. Mr. Pelletier, at Paris, has ſometimes made 60 ounces of it at once; and in one year he made upwards of 300 pounds of it. *(Journ. de Phyſ.* 1785. Jul.) The only nicety is in the choice of the veſſels, and management of the condenſation, which muſt be ſo contrived as to allow a very great quantity of gaſes produced during the operation to eſcape. Theſe gaſes ſeem to ariſe from the water of the acid, and its action on the charcoal and the phoſphorus nearly formed. It acts on theſe ſubſtances in the form of vapour, therefore in the moſt extenſive ſurface poſſible, and furniſhed with great ſtore of heat. With the charcoal it forms inflammable air of the heavy kind, as we ſhall learn afterwards; and with the phoſphorus it forms a gas which takes fire when it comes in contact with the external air. This immediately kindles the inflammable air which iſſues along with it, and the whole produces a bright flame. The gaſes are not formed in an equable manner, but by ſudden paroxyſms, or exploſions, which frequently burſt the veſſels. Mr. Hellot found it neceſſary to have a hole in the receiver, lightly ſtopped with a wooden peg, which was blown out when the vapours became too elaſtic. Other chemiſts had a tube, which communicated with the receiver, and had its mouth immerſed. A ſmall quantity of generated phoſphorus was ſaved in this way.

Having thus learned how phoſphorus may be obtained pure, we are

curious to learn how its acid comes into the compoſition of animal bodies; for phoſphorus muſt ſurely be added to the liſt of ſimples which the French chemiſts allot to the formation of animal and vegetable ſubſtances. There is reaſon to think that it is introduced into them from the vegetable ſubſtances by which animals are ultimately nouriſhed. Margraaf obtained phoſphorus from the charcoal of wheat, rye, and other nutritive vegetable ſubſtances. Whence theſe receive it is a queſtion not ſo eaſily anſwered. It may be produced in them by the powers of vegetation. For we know that there is in vegetables a power to combine their elements together in different ways, ſo as to generate productions which would not otherwiſe be formed. Oil, ſugar, &c. are manifeſtly formed in the veſſels, or organs of plants, of materials which before were of a quite different nature *.

But a quantity of this acid has alſo been found in ſome foſſil ſubſtances; for example in the green ore of lead. There is alſo a bed of ſtone in Spain, in the province of Eſtramadura, and diſtrict of Truxillo, near Lagroſana, which contains this acid united to calcareous earth, as copiouſly as the earth of bones does. This was diſcovered by Mr. Bowle, and communicated to the French Academy by Mr. Prouſt. It forms very extenſive ſtrata, reſting on quartz; is of a white colour, and fibrous texture, not ſo hard as to ſtrike fire with ſteel, but hard enough for building. It is ſo employed for the houſes and incloſures. Thrown into the fire, it burns faintly, with a

* We muſt, as yet, ſuppoſe that the phoſphorus exiſts in the ſoil, and is taken up by the vegetative functions of the plant; for we have no authority to ſay that it is a ſubſtance compoſed of more ſimple ingredients. But further, as thoſe plants now mentioned will grow and thrive in pounded glaſs moiſtened with diſtilled water, enjoying at the ſame time the benefit of air and light, we muſt, if they yield this ſalt when ſo raiſed, look for phoſphorus in theſe ſources. This leads to very nice ſpeculations. I found it, in very great quantity, in a piece of fine coral rock from Port Royal, in Jamaica; and am inclined to think that all corallines contain it, and that, by a proper treatment, they may be rendered true phoſphori, like the Bononian ſtone, without the ſulphur employed in that preparation. EDITOR.

pretty, green light, which it keeps for ſome time after being taken out of the fire. A foſſil of the ſame kind was diſcovered by Werner at Lunenberg in Saxony, and at Slackenwald in Bohemia, cryſtallized in hexahedral priſms, and in plates, generally mixed with fluor, ſpar, lithomarga, and ſteatites, but rarely with quartz. The pure ſpecimens are called APATIT by the German foſſiliſts; and they ſay that it contains $\frac{9}{20}$ths of phoſphoric acid.

I think that a ſtone, forming thin white ſtrata, near the Giant's Cauſeway in Ireland, is of this nature; and perhaps the *lapis ſuillus*, and other fœtid marbles are ſo *.

III.—SULPHUR.

This is the next inflammable body in the order in which I propoſed to conſider them. Its common appearance is too familiar to need any deſcription. When held in the warm hand, we feel it crackle, and even hear it. This is a real ſplitting; and the ſame thing is obſerved in the large cryſtals of ſaltpetre, and ſome other ſalts. It ſmells when rubbed, and becomes highly electric.

Several of its properties have already been occaſionally noticed. It has long been an object of great attention by the chemiſts, and has acted the chief part in all their explanations of phenomena. It was conſidered as the firſt principle of metallization, and of every ſpecies of combuſtion. It has now ſunk to the condition of a ſimple ordinary chemical ſubſtance, of vaſt extent indeed, exiſting in an endleſs variety of bodies, but deprived of all its former pre-eminence.

* It may be adviſable to obſerve with ſome care the vegetation of the Spaniſh diſtrict now mentioned. If this ſtratum of phoſphat crops out on the ſurface, it is not improbable that its rubbiſh will affect the vegetation. Experiments ſhould be tried with plants raiſed on powder of this ſtone, eſpecially of ſuch plants as are ſuperficial. It is moſt probable that plants ſo raiſed will take up ſome phoſphoric acid, or phoſphorus. If they do not, the origin of it in plants and animals is not a little myſterious; and ſpeculations on this ſubject ſeem to open a door to much reſearch, which may greatly affect our current theories. EDITOR.

Sulphur melts and evaporates without change, in very moderate heats; but with ſome peculiarities that are worth mentioning. When heated to 170° of Fahrenheit's thermometer, it begins to evaporate, and we feel a very diſagreeable ſuffocating ſmell. This, long continued in open air, produces a conſiderable change in it, which we ſhall not conſider at preſent. In cloſe veſſels, there is no ſuch change; but at 185° or 190° it begins to melt, and before 220° it is fluid. If the heat be quickly increaſed, it loſes its fluidity, and becomes firm, and of a deeper colour. It regains its fluidity, if we reduce the temperature; and this may be repeated at pleaſure in cloſe veſſels, if the changes of heat be not too ſlow, otherwiſe it begins to evaporate ſo copiouſly, that we cannot apply heat in ſufficient plenty ſuddenly to raiſe its temperature. Theſe peculiarities were firſt obſerved by the eminent naturaliſt Fontana.

If, after being quite melted, we let it cool, it congeals in a cryſtalline form, but ſo confuſedly, that we cannot eaſily define the ſhape of the cryſtals, further than that they are ſlender interlaced fibres. If a great maſs be kept fluid below, while it fixes at the ſurface, the cryſtallization there is much more diſtinct. If melted ſulphur be poured into water, the congealed maſs has a conſiderable pliancy; but this does not laſt.

When heated in open air above 300°, it takes fire and burns with a very weak blue flame. By this inflammation it is totally changed, and from being a ſolid, mild, taſteleſs ſubſtance, now becomes a fluid immenſely corroſive, and in the higheſt degree acid, being now what you are well acquainted with by the name of *vitriolic* or *ſulphuric acid*.

When this acid is treated in a red heat, and in contact with an inflammable body, it is changed into ſulphur; and any inflammable body whatever will anſwer, if it can be made to bear the heat. Even inflammable air will do.

Hence it was inferred by Dr. Stahl, that there was a principle common to all inflammables, and the cauſe of their inflammability,—the

PHLOGISTON. Hence it was inferred that ſulphur conſiſted of the peculiar acid now ſpoken of, and phlogiſton; and that this phlogiſton was expelled during inflammation, but reſtored to the acid by any inflammable body, in conſequence of a greater attraction for the acid.

But no perſon ever ſaw this phlogiſton in a ſeparate ſtate, or could prove that there was ſuch a thing in ſulphur. Mr. Lavoiſier firſt obliged the chemiſts to attend to a thing which they had either overlooked, or accounted for in an unwarrantable manner,—namely, that the weight of the acid is vaſtly greater than that of the brimſtone from which it is produced. From eight grains of ſulphur we can produce twenty-ſix of vitriolic acid,—part of this indeed is water, collected from the atmoſphere, but by no means the whole. Moreover, he found that in burning, the ſulphur abſorbed and attached to itſelf a great quantity of the pure part of the air; and at laſt, he found, by careful meaſurement, that it abſorbed a quantity exactly equal to the augmentation of its weight by inflammation; and he gave good reaſons,—reaſons which have at laſt been acquieſced in, that this air is the cauſe of the acidity of vitriolic acid,—he therefore called it *oxygen*.

Sulphur, therefore, is now conſidered as a ſimple ſubſtance, and ſulphuric acid is a compound of ſulphur and oxygen; and in this light I ſhall continue to conſider it.

At the temperature of 140°, or 150°, ſulphur begins to attract oxygen ſenſibly, and if the heat be increaſed to 180°, or 190°, the combination becomes pretty rapid, accompanied by a faint light; and if this be long continued, the ſulphur will be converted into acid, in the form of ſuffocating ſteams. But the heat is inſenſible,—at leaſt, it is ſo weak, that the inflammability of the ſulphur in gunpowder will be completely deſtroyed without ſetting fire to the charcoal, and the powder is now quite uſeleſs. This is ſimilar to what happens in phoſphorus and many other inflammable ſubſtances. It is an imperfect, or rather a a ſlow inflammation, which will be noticed more particularly in the ſequel.

When ſulphur is evaporated in cloſe veſſels, it ſublimes into a fine duſt or powder, called *flowers of ſulphur*,—they are fine cryſtals, generally a little acid, by reaſon of the air which filled the veſſels. This acidity may be removed by waſhing the flowers in water.

I come now to conſider the properties of ſulphur diſcoverable by mixing it with other bodies.

Sulphur unites readily with the fixed alkalis, as you have already ſeen, eſpecially when they are cauſtic; and this combination is effected both in the dry and the humid way. It combines alſo with all the alkaline earths, and the compounds are called SULPHURETS. It can alſo be combined with volatile alkali. It then forms a volatile hepar, called alſo *volatile tincture of ſulphur*. This combination of ſulphur with volatile alkali is had by mixing together two parts of the muriat of ammonia, two parts of lime, and one part of ſulphur, and diſtilling the mixture briſkly. The ſulphuret does not begin to form till towards the end of the operation; the lime immediately detaching the ammonia in its pure ſtate. This volatile hepar is mixed, but not compounded with the pure volatile alkali. It may be ſeparated, and will even cryſtallize.

The propenſity which ſulphur has when thus combined with alkaline ſubſtances, and diſſolved in water, to abſorb oxygen more quickly and eaſily than when it is pure, was formerly noticed. In its pure or ſeparate ſtate, or even when combined with alkaline ſubſtances, *viâ ſiccâ*, it does not attract oxygen, except when it is heated to ſuch a degree as to make it melt and begin to evaporate. Then indeed its union with oxygen begins to take place, or it enters into a ſtate of imperfect inflammation. But, when united with alkaline ſalts or earths, and at the ſame time diſſolved in water, it gradually attracts oxygen from the air to which it is expoſed, and is thus changed into ſulphuric acid, without needing the aſſiſtance of heat. You doubtleſs recollect examples of this when I was conſidering the

different kinds of gas, and the experiments by which Scheele and Lavoiſier demonſtrated the compoſition of atmoſpheric air.

There cannot be a doubt but that this increaſe of its diſpoſition to attract oxygen proceeds from the change induced upon its coheſive attraction by the alkali.

Many of the foreign chemiſts explain this in another way. Sulphur, ſay they, attracts oxygenous gas ſo weakly in low heats, that it cannot take it from the air in that form; but being mixed with alkali, this prevents the firſt approach to ſaturation of the ſulphur with oxygen, by its attraction for the naſcent ſulphuric acid, with which it inſtantly unites and forms a ſulphat. This is carried off by the water, and leaves the reſt of the ſulphur equally ready for combination.

The attraction of ſulphur for alkaline ſubſtances is not very ſtrong. It may be ſeparated by any acid, even the carbonic; and in the moment of this ſeparation, the mixture emits a gas or elaſtic fluid. If the acid be poured on a dry hepar ſulphuris in powder, the copious eſcape of this hepatic gas occaſions a briſk effervеſcence, although the hepar has been prepared with a cauſtic alkali.

This hepatic gas has very ſingular properties.

1*mo*, It has an intolerably offenſive ſmell, which is commonly ſaid to reſemble the ſmell of rotten eggs. Indeed, the vapour coming from an egg when boiled, whether freſh or rotten, contains this gas, and blackens ſilver, &c. like it. If a bit of hepar ſulphuris, a boiled egg, or a piece of newly manufactured horn, be ſhut up in a cupboard, all the ſilver in it will be ſtained almoſt black in a few days,—a few hours will ſtain it brown.

2*do*, It can be condenſed into a ſort of oily-like matter by intenſe cold, as appears from experiments of Mr. Monge, narrated by Fourcroy in his *Preliminary Diſcourſe, page* xxxi.—*Kerr's edition*, 1788.

3*tio*, In its elaſtic or vaporous ſtate, it is highly inflammable, and burns ſomething like hydrogen gas, but not ſo rapidly; and while it burns, a ſmall quantity of ſulphur is ſeparated from it. The ſulphur

alſo undergoes a ſlight degree of inflammation, and is in part changed into ſulphurous acid. This gas is much heavier than the hydrogenous. It unites with alkalis, in the ſame manner as the hepar from which it was produced; and is ſeparated without decompoſition by an acid, provided that acid do not too readily part with ſome oxygen.

The nature of it was not underſtood, until the late improvements were made in our ſcience by the ſtudy of gaſes or elaſtic fluids. It is now conſidered as an hydrogen gas, holding a ſmall quantity of ſulphur combined with it. *(See Note* 10. *at the end of the Volume.)*.

The inferior degree of rarity, or of elaſticity and volatility, which it has, when compared with pure hydrogen gas, proceeds from the ſulphur which it contains. The ſulphur, by its attraction for the hydrogen gas, diminiſhes its volatility, and therefore renders it a denſer or heavier fluid, and diſpoſes it alſo to be condenſed by a great degree of cold; and, probably from the ſame cauſe, it derives an aptitude to be condenſed or abſorbed by water, to which it communicates its own deteſtable odour. Hence the ſmell of ſulphurous mineral waters, and the depoſition of ſulphur obſerved at many ſuch ſprings.

If ſuch water, however, be expoſed to the air, or put into bottles, without uſing every poſſible precaution to prevent the eſcape of the elaſtic matter, a part of the gas evaporates, or is loſt. And it leaves behind in the water a part of the ſulphur which was united with it. This renders the water milky, and is depoſited by it. Hence the ſulphur depoſited by ſome famous mineral ſprings. This happens in conſequence of the great volatility of the hydrogen gas, which makes it evaporate, carrying away with it a part only of the leſs volatile ſulphur *.

Such water is alſo made to depoſit the ſulphur immediately, by

* Is it not more probable that this decompoſition of the gas, and precipitation of the ſulphur, is effected by the oxygen in the air? This was Scheele's eudiometer, and is perhaps ſuperior to any other.

EDITOR.

adding to it a ſmall quantity of very ſtrong nitrous acid. And the ſulphurous acid produces the ſame effect. But neither the ſulphuric acid, nor the muriatic in its ordinary ſtate, have any power to precipitate the ſulphur; and even the nitric has but little of this power.

It is ſuppoſed that the ſtrong nitrous acid and the ſulphurous acid act by a looſe and ſeparable oxygen, which unites with the hydrogen, and changes it into water. The ſulphur, when alone, not being ſoluble in water, muſt therefore make its appearance in an undiſſolved ſtate. But I cannot underſtand why the ſulphuric and the nitric do not produce the ſame effect. *(See Note* 11. *at the end of the Volume.)*

Several of theſe experiments were firſt made by Profeſſor Bergmann, and alſo by Scheele. Bergmann was the firſt who explained by them the nature of many of the mineral waters called *ſulphurous waters.*

They have the odour, and the other properties, more or leſs, of an artificial compound of water with this gas. This will be exhibited again hereafter, when we deſcribe the mineral waters.

The authors who have thrown the moſt light on the formation of this gas, are a little ſociety of chemical philoſophers in Holland, Meſſrs. Von Deiman, Trooſtwyck, and others, who have publiſhed a volume or two of their experiments on different ſubjects. Their doctrine on this ſubject may alſo be ſeen in the 14th volume of the *Annales de Chymie*, at page 294.

According to theſe gentlemen, a ſmall portion of the diſſolved ſulphur acts on a ſmall portion of the water, ſo as to take its oxygen from it. The ſeparated hydrogen of that ſmall portion of the water does not immediately aſſume the form of a gas, but is joined to the remaining unchanged ſulphuret, attaching itſelf to it by an attraction for both the ſulphur and the fixed alkali. But when we add an acid to ſaturate the alkali, the ſeparated hydrogen has nothing left with it but the ſulphur, the attraction of which is not ſufficient for entirely repreſſing its volatility. It therefore aſſumes the form of gas, aided in this

by the heat produced or extricated by the action of the acid and alkali on one another. And while it aſſumes the form of gas, it volatilizes a part of the ſulphur, which is combined with the gas thus produced *.

This hydrogenous ſulphuret has already come before us, while we were conſidering ſulphur in its connection with the alkaline ſubſtances.

We come next in order to conſider its relation to the acids. Its relation to the ſulphuric acid is already known.

We may foreſee what will be the effect of mixing ſulphur with the nitric acid. It muſt be very ſimilar to that of a mixture of phoſphorus with it. Accordingly, if we pour on a quantity of ſulphur twenty times its weight of nitric acid, and diſtil it, we ſhall obtain ſulphuric acid double the weight of the ſulphur. This ariſes from the very looſe and ſeparable ſtate of the oxygen in nitric acid. For the ſame reaſon, this change may be produced by the oxygenated marine acid.

You all know that melted nitre forms the ſulphuric acid with rapidity and vehemence, by deflagrating it with ſulphur. For we have in the crucible a ſal polychreſt, or ſulphat of potaſh.

Phoſphorus can be combined with ſulphur in the way of fuſion and ſublimation, in a retort and receiver. Margraaf formed a compound of this kind, in which the attraction of both theſe inflammable ſubſtances for oxygen appears to have been more powerful than when in their ſeparate ſtate. The compound took fire, and burned with

* This explanation ſeems both gratuitous and embarraſſed. We aſſume, without warrant, that water is decompoſed, and is afterwards recompounded. In the *Ann. de Chymie, vol.* 14. *p.* 311. the hepar ſulphuris is ſuppoſed to decompound the water, not of itſelf, but by help of an acid, whoſe caloric forms a hepatic gas with the hydrogen and part of the ſulphur. But here the decompoſition of the oxygen becomes ſtill more myſterious, and we cannot ſee why the hydrogen, which at firſt detached the caloric from an acid, ſhould afterwards let it go, and again unite with the acid and compoſe water.

EDITOR.

violence, whenever it was expoſed to the air *. The chemical combination of theſe highly inflammable ſubſtances produced this effect probably by a diminution of their coheſive attraction.

Natural Hiſtory of Sulphur.

Sulphur is to be found in all the kingdoms, as they are called, of nature. It is formed by the decompoſition both of animals and vegetables. The fœtor of animal excrements is found to ariſe from hepatic gas. A conſiderable quantity of ſulphur was collected in cleaning an old common ſewer at Paris. (*See Chaptal, tom.* i. *p.* 91.) The ſame gas is found in all putrid collections of decaying vegetables. The pit in which flax is ſteeped, year after year, impregnates the clay around it to ſuch a degree that it burns with a blue ſuffocating ſmoke. Nay, ſulphur is found in the juices of ſome plants, particularly the *rumices* or *docks*.

But it is moſt abundant in the mineral kingdom. And there it is generally in a ſtate of combination, chiefly with metals. The ores of moſt metals contain it. But the ore or mineral ſubſtance, moſt remarkable for the quantity of ſulphur which it contains, is the PYRITES, in which the ſulphur is combined with iron or copper,—chiefly, however, and oftener, with iron. This compound is of metallic opacity and luſtre, and a pale braſſy colour. It is found in entire veins, or ſometimes in ſeparate maſſes. It generally is ſo found

* I rather think that Margraaf's account of it indicates leſs inflammability. It inflamed with ſome difficulty, he ſays, by friction, giving a yellow light. A dry heat, equal to that of boiling water, cauſed it to burn with violence, giving a ſtrong ſmell of hepar ſulphuris. It ſwelled in water, imbibing much of it, and rendered the water acid and ſulphurous. The water into which it dropped in the diſtillation effervеſced violently with alkalis.

This is a very curious and ſomewhat puzzling experiment. Whence did the acid come, and what was it? Did the compound decompoſe the water, and become oxydated? EDITOR.

among coal. Relics of animal and vegetable ſubſtances are frequently found completely penetrated with it, and, as it were, changed into pyrites. In the iſland of Sheppey, and other parts of Kent, ſuch ſpecimens are very abundant; particularly vaſt quantities of the *cornu ammonis*, ſome of them of enormous ſize. What is curious, the ſhell only is penetrated with pyrites, and its hollows are filled with ſandſtone or other common matters. Pyrites is alſo found very frequently cryſtallized. The cubical braſs-like cryſtals in common ſlate are the pureſt ſpecimens of iron pyrites that I know. But there is a vaſt variety of other forms, many of them very beautiful, adhering to almoſt all ores and ſpars in metallic countries. Theſe cryſtals are commonly the moſt ſhowy parts of a foſſiliſt's cabinet.

It is only from the richeſt pyrites that ſulphur is now extracted. Such as give leſs than one-fifth of their weight are not worth the labour and expence; but are long roaſted in open heaps, to drive away the ſulphur, and reduce the pyrites into a ſtate fit for ſmelting for its metal. In ſome of theſe heaps, cavities are left in proper places, into which the ſulphur, which evaporates or melts from the reſt of the heap, is directed and there collected.

Very rich pyrites are treated for their ſulphur by a rude kind of diſtillation. The retorts are nothing but conical earthen pipes, about four feet long, ten inches wide at one end, and two at the other, and open at both ends. The furnace is an oblong ſpace between two walls three feet aſunder, having ſeveral holes in the roof for the ſmoke, and alſo a row of holes in the floor, to admit air to maintain the fire. The conical pipes lie acroſs this gallery, the wall on one ſide having holes ten inches wide, and the oppoſite wall having as many two inches wide. Thus the pipe fits both holes, and is made tight with lute. It lies with a ſmall deſcent towards the narrow end, which projects three or four inches, and a rude receiver is there joined to it. The lumps of pyrites are put in at the wide end, and when the pipe is full, that end is ſhut up by a round tile luted into

it. The narrow end of the pipe is alſo plugged with a bit of tile ſhaped like a ſtar. This allows the melted or vaporized ſulphur to get out, but keeps in the lumps of pyrites. The ſpace round the pipes being filled with fuel, the fire is kindled, and kept at a moderate heat, by opening or ſhutting the holes in the roof. The ſulphur melts and evaporates, and runs into the veſſels under the ſmall end of the pipes; and when no more runs, the tile is taken out of the wide end, and the effete pyrites are raked out, and freſh put in immediately; ſo that the work is not interrupted. The pyrites taken out ſtill retains ſulphur. This is driven away by roaſting them in a heap, and then the remainder is ſmelted for its metal.

But the greateſt part of the ſulphur uſed in Europe is obtained much more eaſily. It is found in vaſt abundance, ready formed, in the volcanic countries, particularly at Solfatara in Italy. It is undoubtedly produced in thoſe countries in the ſame way that we produce it by art. The ſubterranean fires are occaſioned chiefly by the decompoſition of the matrices of ſulphur; and they act on them in the ſame way as the fires in our laboratories, cauſing the ſulphur to fly off in vapours through every fiſſure and cavity. It ſublimes into thoſe cavities, and collects in vaſt quantities, ſo as even to break down by its own weight. The vapours even penetrate upwards to the very ſurface, impregnating even the ſoil, ſo that the very earth taken up with the ſpade will yield ſulphur. In the cavities, and adhering to the ſtones and rubbiſh, it is often found pure and cryſtallized,—ſometimes tranſparent. This is called *ſulphur vivum*. But it is generally foul, like what is obtained from the pyrites.

Crude ſulphur is contaminated by earthy matters diffuſed in it, and alſo by metals which are in ſome meaſure united to it. It is purified by melting, and keeping for ſome time fluid; by which means the impurities ſubſide, and the pure ſulphur is raked off, and poured into moulds which form it into the little rolls in which we commonly ſee it.

It is alſo purified more completely by ſublimation. For this purpoſe, a furnace, holding a pot, in which the ſulphur is melted, is built at one end of a room, which is ſhut on all ſides, and has the walls, ceiling, and floor, covered with lead or a proper cement. The ſulphur riſes from the pot in ſteams, which are condenſed on the walls, ceiling, and floor, in the form of fine duſt, called FLOWERS OF BRIMSTONE. Theſe are ſometimes a little acid, owing to the air which originally filled the room, the oxygen of which decompoſes ſome of the ſulphur. They muſt be cleared from it by waſhing before the ſulphur can be uſed for all purpoſes of medicine.

The medicinal preparations of ſulphur are not many. It is combined with quicklime, in the moiſt way, forming a calcareous hepar, which we have paid ſufficient attention to already: But this is only a previous ſtep for the preparation of LAC SULPHURIS, by precipitating the ſulphur with any acid. The muriatic is the one preſcribed in the London Pharmacopœia for this purpoſe.

Sulphur is alſo combined with ſome oils, to compoſe BALSAMS OF SULPHUR,—nauſeous medicines, having a moſt offenſive fœtor, occaſioned by emanation of an inflammable gas.

The chief preparation from ſulphur, and it is a very important one, is its acid. This can be obtained only by inflammation, for we need not ſpeak of the proceſs of diſtilling a great quantity of nitric acid from ſulphur. This, indeed, gives the acid, but in a way vaſtly too expenſive. In the ordinary way of burning ſulphur, the acid is obtained in a volatile ſuffocating form. It is an acid vapour, holding, but very ſlightly, a conſiderable portion of ſulphur in ſolution, and a great quantity of water, collected from the atmoſphere. It is what we named *ſulphurous acid.* That this is its nature and compoſition, is proved by diſtilling vitriolic acid, into which a bit of ſulphur, or almoſt any inflammable ſubſtance, has been put. If we expoſe ſome of this volatile acid to vital air, under a glaſs, it will abſorb it in a minute, gain weight, and loſe entirely its volatility and ſuffocating fumes,

becoming *ſulphuric acid.* This is not altogether by ſaturating the redundant ſulphur, for ſome of it is precipitated.

Sulphurous acid is ſcarcely acid to the taſte; alſo its chemical relations as an acid are exceedingly weak, ſo that almoſt any acid will detach it from an alkali. It has diſtinguiſhing properties; particularly that of quickly diſcharging vegetable colours. The ſuffocating vapour of burning brimſtone will make a red roſe white in a few minutes. It is employed for whitening woollen, and ſilk, and linen goods. This volatile acid could not be obtained in a tangible form, were it not for the moiſture diffuſed through the air; and it is this alone which makes it liquid in the old proceſs. This proceſs was to burn ſulphur with a ſmall flame, under a large glaſs bell, kept cool by a wet cloth. The acid formed on its inſide, and thence it dropped into a funnel. This produced the *ſpiritus ſulphuris per campanam*, now called ſulphurous acid, to denote its redundancy in ſulphur.

To obtain ſulphuric acid free from theſe ſuffocating fumes, we need only expoſe the ſulphurous acid to the air. The redundant ſulphur partly attaches to itſelf more oxygen, and partly is loſt, perhaps by precipitation in the air.

The manufacture of ſulphuric acid, in the ſtate which it is required in chemiſtry and the arts, is a very difficult proceſs; and a very lucrative manufacture to thoſe who are poſſeſſed of the ſecret. It is, as yet, in very few hands. This much is known of it, that the ſulphur is kept burning in a pot, ſet on a ſmall furnace, built at one end of a chamber which is cloſed on all ſides, and lined and floored with lead. Water is kept on the floor, to aid the condenſation of the acid vapours. Nitre is employed, mixed with the ſulphur, before inflammation. This maintains the combuſtion, which otherwiſe would ſoon ceaſe, becauſe the ſulphur quickly abſorbs the oxygen of the air that fills the chamber in which it is burned, and its vapours condenſed. The remaining azote, and the acid vapours already produced, ſoon put an end to the inflammation: The nitre maintains it by ſupplying oxygen. But nitre

is a very coſtly article, and no more can be afforded than what juſt keeps up the inflammation. Even with this help, a great many nice contrivances are practiſed in the great manufactures of Great Britain, (which alone, as yet, poſſeſſes the ſecret) to keep up the inflammation; and, after all, the acid is loaded with much redundant ſulphur, and is very weak, becauſe much water was employed for condenſing the vapours. It muſt therefore be concentrated. This would be a ſimple operation with ſulphuric acid, which is much more fixed than water. We needed only to evaporate the ſuperfluous water. But here it is difficult, partly becauſe the volatile ſteams contain ſulphur, which would be loſt, and partly becauſe, in a very diluted acid, the water will carry off much acid. It is concentrated by a diſtillation in great retorts, ſeveral times repeated, in a way which would be tedious to deſcribe, but which a little reflection on the properties of the ſubſtances will ſuggeſt to you. Attempts have been made to ſupply oxygen in this part of the proceſs by means of manganeſe, a mineral of low price, which contains much of it very looſely combined. The acid muſt be dephlegmated till it acquire a ſpecific gravity almoſt twice as great as that of water. It muſt be at leaſt 1,6 or 1,7 before it is fit for diſſolving indigo for the dyers.

When fully ſaturated with oxygen, it ſeems to contain ſeven-tenths of ſulphur, and three-tenths of oxygen.

IV.—CHARCOAL.

Charcoal is the fourth kind of inflammable matter which I enumerated, and which deſerves a ſeparate conſideration.

What is commonly called charcoal is not produced by nature, though there are native inflammable ſubſtances which approach to it nearly by their qualities and conſtituent parts. But they are known by other names. What is commonly meant by this term is artificial, and produced from wood, by burning it, or rather ſcorching it with a ſmothered fire, until it be red hot, and then ſtopping the further pro-

greſs of combuſtion, by covering it ſo cloſely as to exclude completely the further action of the air *.

This proceſs is practiſed, as I ſaid, with wood only, when we wiſh to prepare what is commonly called *charcoal*, which is employed in refining iron, preparing ſteel, &c. But a ſimilar product may be obtained, by ſimilar treatment, from all vegetable and animal ſubſtances, and from the bitumens; all of which, if heated gradually until all their volatile matter is expelled, and with proper precaution to prevent inflammation, will afford charcoals. Such is the charcoal from pit-coal, called COAKS. Small pieces of charcoal may be finely prepared for experiments, by plunging a piece of hard wood into red hot lead, and keeping it there till all ebullition or eruption of vapours of any kind is over; or by putting it into a crucible with good ſand, and luting on a cover, to prevent all action of the air, and then keeping this for an hour or more in a red heat. Dr. Prieſtley obſerves, that charcoal which is made with extreme ſlowneſs retains much inflammable matter, which a haſty operation diſſipates in vapour; and that, after it has ſo retained it, no heat can afterwards diſſipate it in cloſe veſſels.

All theſe ſubſtances from which charcoal can be prepared contain a conſiderable proportion of inflammable matter. Their other conſtituent parts are a ſmall portion of earth and ſalts, and a large quantity of water. By the action of the ſmothered heat, the water is diſſipated, partly alone, in watery ſteams, partly combined with other matters, in oily or ſooty vapours, which are ſtill very inflammable. But a particular kind of the inflammable matter remains united with the earth and the more fixed ſalts, and with theſe conſtitutes the charcoal that is at preſent to occupy our attention.

Charcoal is always black and opaque, and, if produced from a ſolid ſubſtance, ſuch as wood, bone, or the like, generally retains the exter-

* Vide Les Arts et Metiers, CHARBON.

nal form, and ſome appearance of the organic ſtructure of the maſs from which it was produced.

Charcoal thus formed is diſtinguiſhed among the inflammables by ſeveral remarkable and peculiar qualities:

1ſt, When we expoſe it to the action of heat alone, and take care that all acceſs of freſh air to it be effectually prevented, it appears to be perfectly fixed and unalterable by heat. The utmoſt violence of heat applied in this manner has no power either to melt it or to volatilize it. Dr. Prieſtley, it is true, thought that he had converted charcoal totally into a ſpecies of inflammable air by the action of heat alone. He made the experiment by placing the charcoal in a vacuum of an air-pump, and directing the focus of a burning glaſs on it. But there is great reaſon to ſuſpect that this effect was not produced by the action of heat alone, but by that of heat and watery vapour applied at the ſame time to charcoal. That watery vapour, aſſiſted with a red heat, very quickly conſumes and volatilizes charcoal, is now very certain, from the experiments of Mr. Lavoiſier, Dr. Prieſtley, and others; viz. thoſe already mentioned, which were made by puſhing the ſteam of the water through a red hot tube, in which different ſubſtances were expoſed to its action. When the experiment was made with charcoal, it was attended by the production of hydrogen gas and carbonic acid. *This* hydrogen gas from charcoal contains ſome charcoal diſſolved in it, and being thereby heavier than pure hydrogen gas, it is named by ſome authors *heavy inflammable air*, by others, *carbonated hydrogen*.

Mr. Lavoiſier is of opinion that the charcoal is only diſſolved on this occaſion, but not, properly ſpeaking, decompounded. He thinks that it is the watery vapour which is decompounded, and ſupplies the hydrogen gas, the charcoal joining with the oxygenous principle, or baſis of vital air, which the water contains, and being thereby diſſolved and converted into carbonic acid. We have not, therefore, as yet, any proof that charcoal can be volatilized by the action of heat

alone, unleſs we reckon on ſome light black powder obtained in diſtillations of ſulphuric acid from inflammable ſubſtances.

As charcoal ſuffers no change from the moſt violent action of heat alone, ſo it does equally reſiſt the powers of the air and humidity, when theſe are not aided by heat. It is a common practice to ſcorch the ends of ſtakes which are to be driven into the ground, that they may be leſs liable to rot and decay; and this is done with conſiderable ſucceſs. They become thereby a great deal more durable *. But when wood is perfectly charred, we have no experience of any end to its duration. It is totally exempted from any change or decay to which ſo many other ſubſtances are liable by the long continued action of the elements on them.

The knowledge of this incorruptibility of charcoal has given occaſion to a moſt uſeful contrivance, which has been lately thought of, for preſerving water uncorrupted at ſea. Water at ſea corrupts, in conſequence of its drawing a tincture, or diſſolved matter, from the wood of the caſk, which diſſolved matter is a very corruptible ſubſtance. But it has been lately contrived to burn or ſear the internal ſurface of the caſk with flame or hot irons, until that internal ſurface is changed into charcoal, after which it no longer yields any corruptible matter to the water.

Charcoal equally reſiſts the moſt powerful and deſtructive ſolvents. Thoſe which tear into atoms the metals themſelves have not the leaſt effect on it ſo long as the charcoal remains cold. It is only by being heated that it becomes liable to the action of various bodies. In its hot ſtate, all thoſe ſubſtances which are diſpoſed to act remarkably on

* About forty years ago a number of pointed oak ſtakes were diſcovered in the bed of the Thames, in the very ſpot where Tacitus ſays that the Britons fixed a vaſt number of ſuch ſtakes, to prevent Julius Cæſar from paſſing his army over by that ford. They were all charred to a conſiderable depth, and retained their form completely; and were ſo firm at the heart, that a vaſt number of knife-handles were manufactured from them, and ſold as antiques, at a high price. EDITOR.

the inflammable bodies in general ſhew that they have the ſame power on charcoal. Such are the ſulphuric acid, the nitric acid, nitre, the phoſphoric acid, calces of metals, and the vapour of water. Hepar ſulphuris has alſo the power to diſſolve charcoal.

When a pound of ſulphuric acid was diſtilled with half an ounce of charcoal, the charcoal was totally diſſolved, and it changed a part of the acid into ſulphurous acid. The liquor became of a ſea-green colour, which diſappears when the liquor is cooled, and returns when it is again heated. A greater portion of charcoal produces ſulphur, by diſtillation,—the operation is extremely troubleſome,—the production of ſulphur very partial,—and a great part of the charcoal is volatilized, in the form of an impalpable powder, which collects in the neck of the retort, and often chokes it up. The diſtillation may be repeated again and again with the volatilized acid and charcoal, and always produces the moſt intolerable ſuffocating fumes; but the colour at length diſappears. It alſo deſerves remark, that both the ſulphur and the volatilized charcoal appear before any conſiderable quantity of the acid has come over.

Nitric acid alſo acts remarkably on dry charcoal, when very ſtrong. When the mixture takes place properly, it burſts out into a flame. In all caſes, the charcoal decompoſes much of the acid, by depriving it of oxygen, and we obtain nitrous gas and carbonic acid.

We have already ſeen the effect of the acid of phoſphorus on charcoal. It is decompounded by the charcoal, and we obtain phoſphorus and carbonic acid; which laſt muſt be allowed to eſcape.

It diſſolves in hepar ſulphuris both in the humid and dry way, rendering it of a much deeper colour. In the dry way, charcoal combined in a very great proportion, produces very ſingular effects. To produce this combination, however, in the beſt manner, the ſulphur muſt be taken red hot, in its naſcent ſtate, as in the proceſs for pro-

ducing ſulphur *de novo*, by treating charcoal in a red heat with a vitriolic ſalt. In this compound, the united attractions of both the ſulphur and the charcoal for oxygen produces ſuch a rapid combination and heat, that the mixture takes fire when expoſed to the air. Such mixtures are therefore called *pyrophori.* I ſhall conclude this article with a particular account of them.

As heat diſpoſes charcoal to be attacked and decompounded by theſe ſubſtances, ſo does it alſo prepare and diſpoſe it to be acted on by the air. You all know that the conſequence of heating it red hot in the open air is an immediate beginning of its inflammation, during which it is gradually conſumed, and a great deal of heat is produced. The apparent quantity of the uninflammable matter into which the charcoal is changed, or which remains in its place when the inflammation is completed, is a very ſmall quantity indeed, when compared with that of the charcoal before it was inflamed. It is only one-ninth of its weight. But this appearance is a deceitful one. There is a much greater quantity of uninflammable matter produced, but it aſſumes an elaſtic aëreal form, and is diffuſed in the atmoſphere imperceptible to the ſight. It is fixed air, or the carbonic acid gas, the total weight of which far exceeds the weight of the charcoal that has been conſumed. We can collect and condenſe this gas, ſo as to reduce it to a more perceptible form, by the attraction of cauſtic alkalis or quicklime. And there are other ways by which we can render it perceptible, and eſtimate the quantity of it. When this is done with exactneſs, the weight of it is always found equal to the joint weights of the conſumed charcoal and that of the oxygen gas expended in conſuming it, and changed along with it into carbonic acid gas. Mr. Lavoiſier, by a very careful meaſurement, found that 100 parts, by weight, of carbonic acid, contains nearly 72 parts of oxygen, and 28 of charry matter.

We have an example of this in the deflagration of charcoal with nitre. You remember what a blowing noiſe, and ſucceſſion of explo-

ſions, accompanies that deflagration. Curioſity to learn what happens on this occaſion, and what was the cauſe of the aſtoniſhing force of gunpowder, ſuggeſted a contrivance to fire ſome of it, or a mixture of charcoal and nitre, in a ſtrong piſtol barrel, the end of which was ſoldered cloſe, and the touch-hole ſcrewed up. And the quantity of materials fired at once being but very ſmall, there was no report or exploſion; the ſtrength of the machine being ſufficient to confine the flame and elaſtic matter. The only external ſign of the firing of the powder or compoſition was, that the barrel became hot. It was allowed to cool, and then opened under water, by unſcrewing the touch-hole. A quantity of elaſtic aëreal matter came out, which was ſurpriſingly great when compared with the quantity of charcoal and nitre which had been fired. This experiment was made by Mr. Robins, Engineer to the Honourable Eaſt-India Company.

But others having repeated it ſince the nature of the aëreal fluids became a ſubject of inquiry, they found that the elaſtic aëreal matter produced by charcoal and nitre is a mixture of carbonic acid gas and of azotic gas.

Knowing, as we now do, that nitrous acid is compoſed of ſeven parts of oxygen, and three parts of azote nearly, we are enabled to explain very clearly the production of azotic gas during the deflagration of charcoal with nitre. And the other experiments which have been deſcribed to you explain the production of carbonic acid at the ſame time. It appears, that the charcoal when heated, acts by a powerful attraction for the oxygen, which abounds in the nitric acid. By uniting, they form the carbonic acid. The other principle of the nitric acid, the azotic gas, is thus ſet at liberty, and being added to the fixed air, makes up that great quantity of elaſtic aëreal matter which is diſengaged from charcoal and nitre.

There is another production ſometimes obtained from this deflagration, viz. a very ſmall quantity of volatile alkali. This is explained by another late diſcovery which I already mentioned, concerning

the component principles of the volatile alkali, which is now ſuppoſed to be a compound of hydrogen and azote. This being admitted, we can account for the formation of a ſmall quantity of it from ſome of the mixtures of charcoal and nitre. Some part of the water or humidity inherent in charcoal, and in nitre cryſtals, is decompounded during the heat of deflagration, by the attraction of the charcoal for the oxygen of the water. Thus the other principle of the water, the hydrogen, is let looſe, and joining with a part of the azote, forms the volatile alkali. This, however, is in this caſe an accidental production, in ſmall quantity only, and not always perceptible. A chemiſt in Birmingham, whoſe name I do not recollect at preſent, forms volatile alkali in abundance, by paſſing common air over a mixture of charcoal and vitriolic ſalts with an earthy baſis (ſuch as alum or Epſom ſalt) made red hot.

After this explication of the deflagration of nitre with charcoal, I may ſo far take notice of the deflagration of the ſame ſalt with ſulphur, as to remark that the products of that deflagration are accounted for by the ſame principles. The products of the deflagration of nitre and ſulphur, are ſulphuric acid, formed by the union of the ſulphur with the oxygen of the nitric acid, and azotic gas, formed of the azote of the nitric acid and latent heat. The ſulphuric acid, the moment it is formed, joins itſelf to the alkali of the nitre, ſo that very little of it is volatilized.

By the ſame ineſtimable diſcovery of Mr. Cavendiſh, by which we firſt learned the conſtitution of nitrous acid, we can alſo account for what happens in the operation by which the largeſt poſſible quantity of vital air may be extracted from nitre. In that operation, the nitre is expoſed to the action of heat in a ſmall retort of earthen ware, or of glaſs well coated with clay and ſand, and which has a long neck. Sometimes an iron retort or gun-barrel is uſed, but it is not ſo proper. The retort is expoſed to the immediate contact or action of the burning fuel, but heated gradually in the beginning. As ſoon as the re-

tort and nitre begin to be ignited, the vital air begins to come forth. At the firſt it is very pure, provided the nitre be quite free from duſt or admixture of vegetable or animal matter. If ſuch matter be preſent in it, though in exceedingly ſmall quantity, ſome carbonic acid gas is formed at firſt, and comes out mixed with the firſt portions of vital air and ſome azote. After this, or from the beginning, if the nitre was quite pure, we obtain a great quantity of good vital air, which, if not quite pure, contains a ſmall admixture of azotic gas. But, towards the end of the operation, when the heat muſt be increaſed to a higher degree, the vital air comes over mixed with a more conſiderable portion of azotic gas. The reaſon of this difference in the purity of the vital air is, that in the beginning, the nitric acid gives out only a part of the oxygen which it contains, (nearly $\frac{7}{100}$) and it is changed into nitrous acid, retaining perhaps $\frac{65}{100}$, and in this ſtate continues adhering to the alkalis. In the nitrous acid, therefore, there is a deficient proportion of oxygen, and a ſuperfluous quantity of azote. When the proceſs is continued, and the heat increaſed to produce a more complete decompoſition of the acid, the azote muſt neceſſarily make its appearance in a proportion continually increaſing.

All theſe facts, and many more, to be mentioned as we proceed, and which are ſo well explained by Mr. Cavendiſh's diſcovery, confirm the ſolidity of that diſcovery, making it one of the moſt important which the modern chemiſtry has produced.

One of the moſt remarkable properties of charcoal, when recently taken from the fire, is an attraction for a certain quantity of humidity, and for various odorous and colouring matters of different fluids, containing animal or vegetable ſubſtances, ſubject to fermentation or corruption,—as alſo for the acetous acid.

We have proofs of its attraction for humidity in many curious experiments of Mr. Scheele and Dr. Prieſtley. Although indeſtructible by heat in cloſe veſſels without addition, yet, if moiſtened, it will yield carbonic acid and hydrogenous gas. This may be repeated by an-

other moiſtening; and ſo on, till it is all expended in theſe productions. This is evidently owing to its ſtrong attraction for oxygen, in which it exceeds all ſubſtances yet examined. It decompoſes the water,—combining with the oxygen, and thus forming carbonic acid, and thus alſo leaving the hydrogen at liberty.

Its action on odorous effluvia is no leſs remarkable. If laid (freſh made) on ſilk or linen gummed or oiled for umbrellas, a preparation which continues to exhale a heavy ſickening ſmell for many years, it will remove it in a few hours. It ſweetens bilge water, and all kind of corruption that is accompanied with emiſſion of hepatic ammonia. It clears ſaline ſolutions of their colouring matter and rank ſmells, cauſing them to cryſtallize in ſnow-white purity; and is much uſed for this purpoſe in pharmacy; as in the preparation of the *terra foliata tartari*, which was formerly a tedious proceſs, and conſidered as a teſt of pharmaceutical dexterity. It removes in an inſtant the heavy flavour of corn ſpirits haſtily diſtilled. It clears foul camphor in the ſublimation from all fuliginous taints. It ſweetens water which has grown putrid by long keeping. It even ſweetens meat which has already putrified to a very great degree. Mr. Cappe at Lille has publiſhed valuable experiments on this ſubject,—as has alſo Mr. Lowitz an eminent chemiſt at Peterſburgh in Ruſſia. Charcoal is therefore an excellent dentifrice, as very well adapted to the mechanical operation of cleanſing the teeth, and ſtill more as the moſt powerful corrector of all putreſcence, which is the chief cauſe of all diſorders of the teeth and gums.

The acting principle in theſe effects is not yet diſtinctly underſtood. As they are generally accompanied by an immediate and great increaſe of the offenſive ſmells, we are led to aſcribe its efficacy to its attraction for oxygen, by which moſt of thoſe gaſes are ſet at liberty.

Powdered charcoal clears water impregnated with carbonic acid ſo completely that it no more renders lime-water milky.

Charcoal is found to act powerfully in relieving from the pain of heartburn.

In conſequence of its ſtrong attraction for pure acetous acid, it becomes a powerful agent for concentrating it by diſtillation. We are indebted for this, as well as for the full confirmation of the laſt mentioned chemical property of charcoal, to Mr. Lowitz. After having concentrated this acid as much as poſſible by freezing, he mixed it with a great proportion of charcoal freſh made, and diſtilled it till the charcoal was ſeemingly dry; then, changing his receiver, he obtained from this charcoal acetous acid, in the utmoſt ſtate of concentration and purity, and which cryſtallized in a cold little below that of freezing water. This is ſomewhat of an anomalous fact, becauſe charcoal exhibits no remarkable attraction for acetous acid in a leſs concentrated ſtate.

I have already obſerved, that charcoal attracts oxygen more powerfully than any other ſubſtance does that we are acquainted with. We cannot decompoſe carbonic acid by any ſingle elective attraction. Charcoal is employed for ſeparating it from all other bodies; and, in conſequence of this power, charcoal is the great inſtrument in all metallurgic operations; and in all operations by which we reſtore to bodies their quality of inflammability. For inflammability is deſtroyed only by attracting oxygen from the atmoſphere, and becoming ſaturated with it. I have already mentioned the ingenious proceſs by which Mr. Tenant effectedt he decompoſition of the carbonic acid, by means of phoſphorus and an alkaline ſubſtance.

From all that has been ſaid of charcoal, you perceive that there is a principle common to every combuſtible ſubſtance procured by charring combuſtible bodies, and that this principle is exceedingly ſubtile, ſince it is found to compoſe ſo pure a fluid as carbonic acid, or fixed air. You now ſee, that although the black ſubſtance obtained by the ſmothered burning of many bodies be ſolely the production of art, yet the common principle, the *carbon*, ſo called to diſtinguiſh it from the

groſſer body in which it is found, is one of the moſt copious and uniform productions of nature. The calcareous, and other abſorbent earths, muſt now be added to the numerous claſſes of bodies that contain it; and we muſt, in ſhort, conſider every thing as an ore or matrix of carbon, which contains fixed air, or which produces fixed air by union with oxygen.

It is remarkable that a principle ſo abundant in nature ſhould never be ſeen in its native form, pure and unmixed. But this ariſes from its activity and diſpoſition to combine with almoſt every ſubſtance in nature. The wonderful changes of external appearance which may be induced by ſuch combinations, are now ſo familiar to you, that although you may be ſurpriſed, you will not be diſpoſed to doubt, when I venture to ſay that in all probability the native, unmixed, form of carbon, is what is known to the world under the name of the DIAMOND! Surely nothing can be more unlike than the moſt brilliant, the moſt tranſparent of all bodies, to a ſubſtance eſſentially black, and completely impervious to light. You will be eager to know the evidence on which I venture ſuch an unlooked-for opinion.

When conſidering the ſiliceous earths, I obſerved that quartz, cryſtal, and others abounding in them, were diſtinguiſhed from the reſt by ſeveral peculiarities. A remarkable ſmell when they are rubbed together; the light which their friction produces; and ſeveral appearances of elaſtic matter iſſuing from them in their union with fixed alkalis; and their refuſal to unite with other ſiliceous earths, were conſidered by many chemiſts, and particularly by the Chevalier Dolomieu, as indications of inflammable matter in them.

The diamond, beſides theſe qualities, is farther diſtinguiſhed by being totally diſſipated by a violent heat; but this only when expoſed to the joint action of heat and air. Till the neceſſity of this combination was diſcovered, the diſſipation of diamond was conſidered as analogous to the decrepitation of ſalt, and of many foſſils, which may be diſperſed by heat in ſmall fragments, which in ſome caſes are even

a fine powder; but theſe fragments could always be collected, whereas the diamond diſappears altogether. It has long been ſuſpected, therefore, to be inflammable.

Accordingly, ſeveral chemiſts have lately examined it with the expreſs view of aſcertaining this point. Crucibles of fine porcelain, having ground ſtoppers of the ſame ſubſtance, were employed; and it was found that only a part of the diamond could be evaporated in this way; ſo much the more, as the veſſels contained more air. When covered with the powder of charcoal in the crucible, no change whatever was produced by the moſt intenſe heats. When ſo heated in free air, it gradually conſumed, and was all the while of a dazzling brightneſs, much more brilliant than the capſule on which it was lying. Although there may be ſome impropriety in ſaying that diamond is inflammable, like oils, yet it appears to be combuſtible like charcoal. Count Sternbergh, a gentleman in Bohemia, burnt a diamond in oxygen gas, by fixing to the point of it a bit of iron wire, which he made red hot, and then plunged the whole into a veſſel containing vital air. The wire burned with great ſplendour and production of heat, and this being communicated to the diamond, it took fire and burned in the ſame manner. The experiment was repeated in a glaſs veſſel, whoſe inſide was moiſtened with lime-water. It very ſoon became dim, and was totally obſcured, ſo that the progreſs of the combuſtion could not be obſerved. But this gave ſtrong indication of the preſence of carbon in the diamond.

Mr. Smithſon Tenant mixed 2½ grains of diamond duſt with one-fourth ounce of nitre cleared of the water of cryſtallization, and expoſed the mixture in a tube or retort of gold. A good deal of nitric acid was diſengaged before the nitre began to act on the diamond. By this circumſtance, the carbonic gas, produced by the action of the oxygen in the inſtant of decompoſition, was abſorbed by the fixed alkali, for which it has a ſtrong attraction, and it was all retained. This was obtained by diſſolving in water, and adding muriat of lime, which

formed a digeſtive ſalt, and precipitated a crude calcareous earth, and thus gave Mr. Tenant hold of the carbonic acid. He found this calcareous earth to contain $9\frac{1}{7}$ grains of carbonic acid. By Mr. Lavoiſier's repeated examination of the proportion of ingredients in this acid, he found that it held $2\frac{1}{2}$ grains of carbon, which is preciſely the weight of the diamond employed.

By this ingenious experiment, which has been repeated both in London and Paris, we ſeem entitled to conclude that diamond is carbone in a cryſtalline form.

Another experiment leading to the ſame concluſion, has lately been made by Mr. Morveau (Guyton de). He expoſed to an hour's intenſe heat, a diamond incloſed in a tube of iron, put into a crucible, and ſurrounded with a mixture of ſiliceous and argillaceous matter, which had been burnt in a burnt clay crucible. This crucible was incloſed in another, which was coated with a ſimilar compoſition. The diamond vaniſhed entirely, though the tube had no aperture, and the inſide of the tube was converted into perfect ſteel. You will afterwards learn that this change is produced by the union of iron and carbon. You ſee the propriety of Mr. Morveau's precaution to cut off all communication from the fuel to the tube.

The diamond burns at a much lower heat when mixed with nitre, than by any other treatment. When merely heated in contact with atmoſpheric air, a very ſtrong red heat is neceſſary to induce that bright ſhining, which is the indication of its uniting with oxygen, or of burning. When this is done in pure oxygen, the combuſtion begins a little ſooner,—but when mixed with nitre, the combination begins with the loweſt red heat. Mr. Tenant found that common charcoal may be rendered extremely hard, ſo as to ſcratch and work upon tempered ſteel, by long continued ignition in cloſe veſſels; and that by this treatment its tendency to combuſtion is ſo much repreſſed, that it does not begin to burn till red hot. There are ſome very remarkable examples of this kind which have lately come to my know-

ledge. In the dreadful eruption of lava in Iceland, trees growing in crevices of the rocks have been buried under the melted lava, and there charred and covered with melted matter, which has not ceaſed to be red hot for more than two years. Fragments of theſe are ſometimes brought into view by the convulſions and ſhatterings of ſubſequent eruptions, and are called *ſvaërt ſouterbrant*. Some pieces of them in my poſſeſſion require a full red heat for their combuſtion, and they are totally conſumed. I have obſerved the ſame thing in a native coak, lately diſcovered near Newcaſtle, which has been produced by the protruſion of a maſs of melted whinſtone, which now forms a dyke in the ſtrata, and it has charred above two fathoms of the ſeams on each ſide.

Appendix.—Pyrophori.

I conclude this article with the account of a very curious claſs of chemical preparations, which derive their diſtinguiſhing properties from charcoal. They are called PYROPHORI, becauſe they are always in a diſpoſition to take fire and burn whenever they are expoſed to the free air. They are as commonly known by the name of *phoſphori,—light bearers*, (but with leſs propriety), becauſe they have this reſemblance to Brandt's phoſphorus of urine. They are diſtinguiſhed, however, by the name of *Homberg's phoſphorus*, or *phoſphorus of alum*.

This is generally a blackiſh or dark coloured powder, like charcoal, or the half burnt aſhes of combuſtible bodies. It is kept in bottles well corked; and if a quantity be poured out into the air, eſpecially if the air be a little damp and warm, it grows hot, ſmokes, and preſently takes fire, burning like as much charcoal, with a diſagreeable ſmell.

This phoſphorus of Homberg is prepared by firſt roaſting a quan-

tity of meal or flour of any kind, till it is almoſt charred, taking care that it be not completely ſo. This charry powder is mixed with a quantity of alum, deprived of its water of cryſtallization; and the mixture is put into a phial, ſo as nearly to fill it. The phial is ſet among ſand in a crucible. The ſand muſt ſurround the phial as far up as it is filled with the powder. The whole is kept in a moderately hot fire, till all fumes have ceaſed, and a very faint flame, like that of ſulphur, has continued for ſome time. It is now removed, and the mouth of the phial ſtopped with a cork as ſoon as it is cool enough to allow it.

When a little of this powder is ſhaken out of the phial, and formed into a heap, it grows hot, ſmokes, ſmelling ſtrongly of hepar ſulphuris, and then takes fire, if well prepared. If much over or under calcined, it is apt to fail; and it is generally in its beſt ſtate when it has ſomething of a dirty green colour mixed with it, as if it contained powder of ſulphur.

Subſequent experiments and obſervations have ſhewn that any ſalt which contains the ſulphuric acid will do as well as alum for the preparation of this pyrophorus. Scheele obtained the fineſt from vitriolated tartar, or ſulphat of potaſh. Nay, the natural productions, gypſum, fluor, and others, formed by the ſame acid, will anſwer. We know that all ſuch compounds, when treated with combuſtible bodies in a ſtrong heat, produce ſulphur or hepar ſulphuris. Theſe pyrophori may therefore be called *ſulphureous pyrophori*, or perhaps *hepatic pyrophori*. Mr. Scheele has obſerved that the ſteams of hepar ſulphuris generate much heat when they abſorb vital air. It is very probable that the copious abſorption in the preſent caſe, (for it is very copious), may produce enough to kindle the mixture of naſcent ſulphur and charcoal.

This ſubſtance has not yet been examined with the attention which it deſerves; and we are not yet well aſſured of the procedure of nature in its inflammation. Mr. Lavoiſier has beſtowed particular at-

tention on compounds nearly allied to it, in his firſt eſſays, publiſhed in 1777, and alſo in his ſubſequent papers.

There are many other ſubſtances which take fire of themſelves, by the heat produced in the mutual action of their ingredients. Of this we have already ſeen an example in the mixture of nitric acid with eſſential oils; alſo with phoſphorus. We know that the ſame thing happens in many caſes, where vegetable or animal ſubſtances are heaped together in a moiſt ſtate. They ferment, grow hot, and frequently burn, or at leaſt are reduced to aſhes. We ſhall have occaſion to take notice of ſome remarkable examples of this kind as we proceed in our examination of inflammable bodies.

At preſent, I propoſe to beſtow a little attention on another claſs of bodies known by the name of PHOSPHORI, and to which that name does more peculiarly belong. Theſe bodies do not take fire, that is, do not ſuffer a decompoſition of their parts, accompanied with the production of heat and light. The bodies I now mean to conſider only ſhine in the dark, but without any ſenſible heat. And they acquire this faculty, not immediately by expoſing them to the action of the air, but to that of a ſtrong light.

Of theſe there is a claſs very nearly allied to the ſubſtance I have laſt deſcribed, by its compoſition and chemical properties. The moſt remarkable of them, and the firſt obſerved, is that called the *Bolognan phoſphorus*,—the *Bolognan ſtone*, becauſe firſt found in the neighbourhood of Bologna, about the year 1630, by one Caſcarioli, (a ſhoemaker I believe) who obſerved, that when taken from the light into a dark place, it continued to ſhine for ſome time. As ſoon as this was publicly known, ſeveral philoſophers of that time examined the appearances with more care. It was found that two or three ſeconds expoſition to the light was ſufficient to make it ſhine, and that longer expoſure did not increaſe its luminouſneſs. It ſhone for four or five minutes, and ſome fine pieces ſhone for a quarter of an hour. The light of the ſun was the moſt effectual. After this the clear light of

day. Nay, the light of a torch made it ſhine. Moon light had no effect. The light emitted was enough to make the ſmalleſt print legible, when held very near.

Theſe facts attracted much attention, and were very intereſting to the philoſophers of laſt century, who were at that time much divided in their opinions concerning the nature of light. Some imagined, with the vulgar, and with the followers of Newton, that light was a material emanation from the luminous body; while others, with Des Cartes at their head, imagined that light, or viſion, was the effect of a tremulous motion of an elaſtic fluid, as ſound, or hearing, is the effect of the tremulous motion of elaſtic air. The firſt claſs drew ſtrong arguments in ſupport of their opinion from the phenomena of this ſtone, for it ſeems to imbibe the light to which it is expoſed, and afterwards to give it out again.

It is ſomewhat ſingular that ſo curious a phenomenon did not engage the chemiſts of that age in a very minute examination of the conſtitution or ingredients of the Bolognan ſtone, and cauſe them to ſpeculate about the way in which it produced thoſe effects. This inquiry was more ſtrongly ſuggeſted to them by the methods which muſt be taken to make the ſtone a powerful phoſphorus. It muſt be beaten to fine powder, and then made into a paſte with water and oil, and then calcined. But it lay a half century neglected; till, in 1675, Baldwin, a German chemiſt, obſerved that the reſiduum from the diſtillation of the nitrat of lime imbibed the light and emitted it in the ſame manner; and in 1693, Homberg diſcovered the ſame thing in the muriat of lime; and in 1730, Duſay found that many other ſubſtances, when calcined in the ſame way, had the ſame property. A ſeries of curious obſervations of this kind by Beccaria (Giacomo Bartholomeo) greatly augmented this liſt. But although theſe diſcoveries naturally occaſioned ſome chemical examination of the Bolognan ſtone and calcined phoſphori, no addition of knowledge was obtained, till Mr. Margraaf examined them with his accuſtomed ſkill, in 1749.

He found that the Bolognan ſtone was a ſort of gypſum, or a heavy ſpar, containing the ſulphuric acid united to calcareous earth. Subſequent obſervations, however, prove it to be a barytes united to that acid. He found that all heavy ſpars could be made phoſphoreſcent by proper calcination. Leibnitz made the ſame obſervation in the firſt volume of the *Miſcell. Berol.* with reſpect to fluor. Margraaf gives the manner of preparing thoſe ſubſtances in the beſt manner, viz. by pulverizing, and then making the powder into ſmall cakes with a little gum water, then drying them ſlowly, and calcining them amidſt the coals in a reverberatory furnace. So prepared they ſhine like glowing embers. He obtained phoſphori from all earths which contained the ſulphuric acid; and the earth of alum was the beſt, and ſome calcareous ones ſcarcely inferior. Some time after this, Mr. Canton of London produced a ſhining preparation of the ſame kind, by calcining oyſter ſhells half an hour, and then reducing them to powder, and mixing them with one-third of ſulphur. The mixture was rammed into a ſmall crucible, and calcined for an hour in a clear fire. The maſs, when broken, was found unequally luminous. The beſt parts were therefore ſelected, and were very brilliant. It is to be remarked, that different parts emitted light differing conſiderably in colour. Figures may be drawn on paper with white of egg, which will take hold of the powder and exhibit the figure in the dark. Canton's phoſphorus equals any of the natural ſtones in brightneſs, and in the quickneſs in which it is ſaturated with light, ſo as to attain its greateſt poſſible brilliancy. Indeed, in this reſpect, it may be thought ſuperior; for Mr. Margraaf ſays, that two or three minutes expoſure is neceſſary for his preparations. When this light emitted by theſe phoſphori has expended itſelf, or is no more ſenſible, heating the body renews it for a little time; and when this has ceaſed, a greater heat cauſes another emiſſion. But, in all theſe caſes, a greater heat ſooner exhauſts the power of ſhining. In ſhort, in this experiment, heat operates in the ſame way as in expelling dampneſs, or any other volatile

matter. Alſo a great heat applied to the phoſphorus, while it is expoſed to the light, hinders it from acquiring the luminous faculty. All theſe circumſtances concur in ſtrengthening the opinion, that this compoſition imbibes, and then emits ſomething material, which is light, or the cauſe of light. Beccaria ſaid that the Bolognan phoſphorus moſt certainly did ſo, becauſe, when illuminated by coloured lights, it emitted only the colour which had illuminated it. This would indeed be almoſt a demonſtration of the doctrine of imbibition, and of the materiality of light; but the experiments of Mr. Wilſon with Canton's phoſphorus, render this doubtful. Certain parts emitted a particular colour, whatever had been the colour of the illuminating light.

When we reflect on the compoſition of this curious ſubſtance, we cannot but aſcribe its ſhining to the ſame cauſe which produces the inflammation of the pyrophorus of Homberg. They conſiſt of the ſame ingredients, united by the ſame proceſs, and they continue to emit the ſame hepatic odour, though long kept, if kept from damp air. Accordingly, Mr. Macquer conſiders the ſhining of theſe phoſphori as inſtances of a low and imperfect combuſtion, ſimilar to what we obſerve in the phoſphorus of urine, which begins to ſhine when expoſed to the air, and by this ſhining, is ſlowly converted into phoſphoric acid, ſtill mixed however with a very great proportion of unburnt phoſphorus in a volatile ſtate. It is well known too, that ſulphur, fat oils, ſuet, and many other ſubſtances, nay, even gunpowder when heated to a degree far below ignition, emit a faint lambent flame and ſuffocating fumes, which ſlowly conſume them to a certain degree, and that this happens, without their becoming of themſelves ſources of heat ſufficient for the continuation even of this low degree of inflammation. If an iron bar be heated red hot at one end, and allowed to become very hot alſo at the other end, and if we then make a line along it with a bit of tallow, or white bees wax, or ſulphur, or rather make a ſet of detached ſpots, we ſhall ſee them ſhine

with various brightneſs according to their diſtance from the hotteſt part of the bar, and the brighteſt are ſooneſt exhauſted of this faculty. Macquer, therefore, aſcribed theſe and all other phoſphoreſcences to the ſame cauſe, and ſuppoſed that they were caſes of ſlow and imperfect combuſtion. This opinion is very plauſible, and is well ſupported by the emiſſion of the hepatic ſmell, and ſome other appearances. Many kinds of ſpar are very luminous when thus heated. The Derbyſhire fluor is remarkably ſo. Corroſive ſublimate ſhines the brighteſt of all. Next to this is pure chalk, crude magneſia, earth of alum, vitriolated tartar, French chalk, &c. Mr. Wilſon of London obſerved ſimilar appearances in many other bodies,—indeed in moſt bodies of a white colour. Even paper had this property.

But there are circumſtances attending the phoſphoreſcence at preſent under conſideration, which will by no means agree with this explanation. All the emiſſions of light juſt now ſpoken of require the application of heat, and the contact of vital air, and conſume this air in the ſame manner as common combuſtion does. But the Bolognan ſtone, and the phoſphori of this claſs, require nothing but expoſition to the light, and do not require the renewal of the air. Mr. Canton put ſome of his phoſphorus into ſmall glaſs balls, and ſealed them hermetically, and found them as good as ever after twelve months ſubjection to every trial. He found this to be the beſt way of keeping his powdered phoſphorus. After twelve months, two ſeconds expoſition to the ſun made it ſhine, ſo as to make the figures on his watch dial perfectly viſible. An electrical flaſh, or even the light of a ſingle candle, ſufficed for cauſing it to ſhine. Long expoſure to dry air impairs it, and damp air does this immediately. In ſhort, theſe phoſphori only emit the light they have received, or they are rendered luminous by the action of light alone. The firſt appears the moſt probable, becauſe a greater heat occaſions a brighter light and a more rapid exhauſtion of all that will be diſſipated by that heat. This is very like the expulſion of ſomething received. Another circumſtance confirms

this. No length of keeping in the dark will hinder the emiſſion of the light which had been imbibed, and would have been expelled by that heat. A ball kept fifteen months in the dark, after having been illuminated by the moon only, and which did not ſhine immediately after, on account of the weakneſs of the light, was diſtinctly ſeen by plunging it into boiling hot water.

Mr. Canton found that humidity incloſed with the phoſphorus, that it might ſtick to the glaſs, impaired it much, and deſtroyed it. Alcohol did not hurt it ſo much, and æther not at all. Æther, therefore, with a minute portion of reſin or gum, would make the powder adhere as Mr. Canton wiſhed. The phoſphorus might be attached in this way to a plate of glaſs, and another plate laid on it, and the edges ſecured with varniſh and paper paſted round.

Theſe circumſtances evidently diſtinguiſh this phenomenon from ordinary combuſtion. But it were worth while to examine by ſome proper train of experiments, whether the ſhining is effected by the abſorption of vital air, and a ſubſequent decompoſition by the action of freſh light. As humidity ſpoils the phoſphorus, perhaps a permanent compound is now formed which freſh light cannot decompound again. We might perhaps learn this by examining the change produced after a long time on the air which was ſhut up with the phoſphorus in a damp ſtate. It would be proper to try this with two balls, one of them to be expoſed day and night, and the other kept in the dark.

Mr. Wilſon thinks that this phenomenon is not merely an imbibition and ſubſequent emiſſion of light, but rather that light acts on ſome matter in the body, in ſuch a way as to cauſe it to emit light. Thus only, he thinks, can we account for white light being emitted by a part which was illuminated only by a red or blue light.

The foregoing obſervations on the phoſphori, properly ſo called, are, in my opinion, as intereſting to the chemiſt as to the optician, and they are very intereſting to both. To us, they are important,

being nearly connected with the whole doctrine of combuſtion,—a doctrine ſtill full of difficulties, notwithſtanding the very great diſcoveries which have been made. The ſeparability of light and heat by a plate of glaſs, in the valuable obſervation of Scheele, and their ſeeming ſeparability in the preſent inſtances, are undoubtedly facts of great moment in philoſophical chemiſtry, eſpecially when conſidered along with Herſchel's obſervations. The obſervation alſo of Mr. Goettling, that phoſphorus ſhines bright in azote and in volatile alkali, and the ſhining of vegetable and animal ſubſtances, (particularly ſea fiſh) in a certain ſtage of putreſcence, and their ſhining in *vacuo* and other ſituations incompatible with combuſtion, merit a much more careful attention than has yet been given.

The four inflammable bodies which have now been conſidered appear to us in the character of ſimple ſubſtances. I do not mean that they are elements, but only that we are not authoriſed, by any obſervation or experiment, to ſay that they are compounded of other more ſimple ſubſtances known to us in a ſeparate ſtate. We have never decompounded them, nor formed them by the union of known ſubſtances. We have only been able to extricate them from more complex bodies, and to ſhew that they are ingredients in their compoſition.

This ſimplicity, and the manifold relations of hydrogen, phoſphorus, ſulphur, and charcoal, have been of great ſervice to us, by giving us a conception of the remarkable phenomenon of combuſtion, which is incomparably more agreeable to our general knowledge of chemical facts than the ingenious doctrine of Dr. Stahl, and is really ſupported by proofs which ſeem incontrovertible. Even though imperfect, this new doctrine furniſhes us with a fact, formerly unnoticed, which accompanies all combuſtion, namely, the combination of the body called combuſtible with vital air. We ſhall find that this fact, when traced through all other caſes of inflammation, will give us almoſt all the knowledge of chemical changes that we poſſeſs, and enable us to explain a vaſt

number of the moſt complicated operations of nature, inaſmuch as all explanation of phenomena conſiſts in ſhewing that they are particular caſes of general laws or facts already known.

We proceed now to conſider inflammable ſubſtances of a more complex nature: In doing this, I ſhall ſtill endeavour to introduce them to your acquaintance in the order of their ſimplicity, as far as I can perceive any gradation or order in this reſpect. With theſe views I begin with *ſpirit of wine*.

V.—ARDENT SPIRITS.

Vinous Spirit is produced from ſome vegetable ſubſtances by fermentation, and ſubſequent diſtillation; and the vegetable materials which by theſe proceſſes yield the moſt of it are,

1ſt, The ſweet juices of vegetables, in their naturally diluted ſtate.

2d, The ſugar, or ſweet matter extracted from vegetables, when properly diluted with water.

3d, Grain, or other farinaceous parts of vegetables, malted and diluted in water.

4th, Grain, or other farinacea, diſſolved or diluted in water, without being malted.

All theſe are capable of the vinous fermentation, by which the vinous ſpirit is formed; but not all with equal facility and perfection. They ferment the more eaſily and perfectly, and yield the more ſpirit, nearly in the order in which I have now enumerated them.

The nature of fermentation will be conſidered when we ſhall treat of the vegetable ſubſtances in general. It is ſufficient at preſent to know that the vegetable matter which undergoes fermentation, or a part of that matter, is changed by it into vinous ſpirit.

This ſpirit is at firſt diluted and combined in the fermented liquor with a large quantity of water, a portion of vegetable acid, ſome mu-

cilaginous and colouring matter, and a ſmall quantity of a ſubtile and volatile oil.

The ſpirit is ſeparated more or leſs perfectly from theſe ſubſtances by diſtillation, it being more volatile than moſt of them, eſpecially the acid, mucilaginous, and colouring matter. The water is but imperfectly ſeparated at firſt, on account of the ſmall difference of volatility between it and the ſpirit.

To reduce the ſpirit to a ſtate of purity, we muſt perform ſeveral other operations; ſuch as diſtilling it again, once or twice, with a gentle heat, which is called *rectifying*. By this we ſeparate the greater part of the water which had come over in the firſt diſtillation.

But, even after theſe rectifications, it ſtill retains a conſiderable portion of water, and along with it another ingredient, which being very volatile, always ariſes with the ſpirit, though diſtilled ever ſo often. This is the volatile oil which I mentioned as being intimately blended with the ſpirit at firſt. The quantity of it and the flavour are different, according to the nature of the particular vinous liquor which we have choſen, and alſo according to the manner in which the fermentation has been conducted. It is this oily ingredient in vinous ſpirits which produces a diverſity among them in point of flavour. When it is ſeparated from them as much as poſſible they are all alike, or are diſtinguiſhed with difficulty. It is this oil which makes the ſpirit obtained from all ſorts of grain in particular ſo naufeous at firſt, when compared with ſome others. This oil becomes moſt obvious in them when they are haſtily diluted with water, being then more perceptible by its diſagreeable ſmell and flavour, and often by ſome degree of milkineſs, which appears when the ſpirit and water are mixing together, and for ſome time after.

In order to free the ſpirit from this oily principle, and from a portion of the water which it retains too ſtrongly to admit of its being ſeparated by diſtillation alone, we muſt have recourſe to an elective attraction; and the uſual method is to employ the common vegetable

fixed alkali in its ordinary ſtate, or in the ſtate of pearl aſhes. About one pound weight is added to every gallon of the ſpirit, and allowed to remain with it 24 hours. It is diſſolved by the watery part of the fluid, and forms a liquor which remains at the bottom, and cannot be mixed with the ſpirit above it. The ſpirit may therefore be poured off from it into another veſſel, in which we may add to it half a pound more of the ſame fixed alkali perfectly dry. This may not perhaps become perfectly liquid, but it may attract as much humidity as will make it ſoft, and will half diſſolve it. After waiting 24 hours more, the ſpirit may be poured from this alſo into a clean veſſel, and we may make a third addition to it of the dry ſalt. By theſe repeated operations, we bring it to that ſtate of ſtrength in which it no longer imparts any watery humidity to the dry alkali.

Thus we at laſt ſeparate the whole of the water which the alkali can attract from it. But, at the ſame time, the ſpirit receives a diſagreeable taſte, and a yellowiſh colour. This happens in conſequence of its diſſolving a ſmall portion of the alkali, which, acting on the volatile oily matter, produces the yellow colour. The quantity of alkali thus diſſolved, is, however, but ſmall, though it is ſufficient to give the bad taſte and flavour. But in order to ſeparate this alſo, as well as the oily matter with which it is combined, another operation muſt be performed, which is, to diſtil the ſpirit with a gentle heat, until a ſmall quantity of it only remains in the ſtill. The alkali and oily matter will be found remaining with this ſmall quantity in the ſtill; and the ſpirit that has paſſed over in the diſtillation will thus be brought to the higheſt degree of purity and perfection to which it can be reduced by theſe operations.

The artiſts named rectifiers and compounders, who employ themſelves in purifying coarſe ſpirits, and changing their flavour, uſe alſo, in ſome of their diſtillations, a ſmall quantity of the ſulphuric acid, and ſometimes the nitric. Theſe act on the ſmall portion of water, and of the oil which may ſtill remain; and they diminiſh the volatility

of both theſe ingredients; and by their action on the ſpirit itſelf, they communicate more or leſs of an agreeable flavour.

When ſpirit of wine is thus highly purified, it is lighter than water, in the proportion of 82, or 83, or 84, to 100, and in this ſtate it is called ALCOHOL. But I have ſometimes brought it up to an higher degree of ſtrength, ſo that, in the heat of 60° of Fahrenheit, 80 parts of it by weight were exactly equal in meaſure to 100 by weight of water. It was brought to this ſtrength by diſtilling it with the addition of dry muriat of lime, which has a very ſtrong attraction for water, and retains it powerfully in the diſtilling veſſel. This intermedium for rectifying ſpirits has alſo the great advantage of not acting ſenſibly on the vinous ſpirit, and therefore imparts nothing of that diſagreeable ſoapy taſte and flavour which are often produced by the fixed alkalis.

Vinous ſpirits make an article of commerce that is very extenſive. As they derive all their value from the alcohol which they contain, a method for accurately determining how much alcohol, and how much water, there is in any ſpirit, is a very valuable acquiſition. This is beſt diſcovered by the ſpecific gravity. A cubic foot of water, of the temperature 55°, weighs 1000 ounces preciſely. The like meaſure of the pureſt alcohol that I have been able to prepare weighs 800; and ardent ſpirits approach to this levity, in proportion as they contain alcohol. A mixture of equal meaſures of water, and of an alcohol which weighs 820 ounces, forms what is called PROOF SPIRITS. Its ſpecific gravity is 0,925, or the weight of a cubic foot is nearly 925 ounces *.

* There is conſiderable uncertainty in this. *Proof ſpirits* is that ſtrength by which the liquor pays the exciſe duty. The ſtatute by which this is impoſed declares that an Engliſh wine gallon, which is 231 cubic inches, or $\frac{231}{1771\frac{1}{8}}$ of a cubic foot, ſhall weigh ſeven pounds and 12 ounces, avoirdupoiſe weight. This gives $927\frac{6}{10}$ ounces for the weight of a cubic foot. The hydrometers uſed by the officers ſuppoſe it ſtill weaker. (See *Encycl. Britannica*, SPIRITS.) EDITOR.

When a vinous ſpirit is by ſuch operations brought to an high degree of purity, it is an exceedingly fluid, penetrating, fragrant, and highly inflammable liquor, named by the chemiſts ALCOHOL; a word introduced into chemical language by the Arabians, and which means, I believe, ſomething very ſubtile and elaborately prepared.

It is an inflammable ſubſtance, diſtinguiſhed from the reſt by its ſingular qualities.

In the firſt place, it has an extraordinary diſpoſition to retain the form of fluid. The moſt intenſe cold that has yet been obſerved in nature, or produced by art, is not ſufficient to congeal it.

Another remarkable property of alcohol is, a diſpoſition to be much expanded by heat and contracted by cold. It is therefore often uſed in the conſtruction of thermometers.

But thermometers made of it can only be employed in meaſuring intenſe colds, and the heats of the atmoſphere and of animal bodies. In a heat equal to 174° of Fahrenheit, which is far below the boiling point of water, alcohol begins to be changed into elaſtic vapour, which, if allowed to increaſe in quantity, would burſt the thermometer. Its expanſion is not in proportion to its increaſe of temperature.

We may therefore reckon as a third of the remarkable qualities of alcohol, its volatility. In the vacuum of an air-pump it would boil and produce elaſtic vapour in lower heats than the ordinary heats of the atmoſphere. And in an open veſſel, even under the preſſure of the atmoſphere, it evaporates ſpontaneouſly much faſter than water. If a perſon dip one finger into alcohol, and another into water of the ſame temperature, and then expoſe them to a dry air, the finger which was dipped into the ſpirit will immediately feel vaſtly colder than the other, owing to the more quick evaporation, and the rapid abſorption of heat. Its latent heat is ſcarcely inferior to that of water, if it does not exceed it.

A fourth well known quality of it is an high degree of in-

flammability. The vapour of it, in whatever manner produced, is eminently inflammable. Whenever it is touched or approached by flame it immediately takes fire, and burns with a blue tranſparent flame, which has not the ſmalleſt appearance of ſmoke; and the whole of the alcohol is gradually conſumed in this manner, with as little appearance of its leaving any earthy or other fixed incombuſtible matter behind. This, as I formerly obſerved, induced Dr. Boerhaave to conſider alcohol as the pure pabulum of fire, or as a matter which was totally ſpent and conſumed in producing heat and light. And he inſinuates a ſuſpicion that the other inflammable bodies may have their inflammability from alcohol preſent in their compoſition.

But this notion of its being totally ſpent and conſumed by inflammation, and converted into heat and light, was a great miſtake. The fact is, that it is converted into a great quantity of water.

Newman obſerves, that if we burn the pureſt alcohol in a deep veſſel, ſuch as a large braſs mortar, and keep the ſides of it cool by ſurrounding it with cold water, a quantity of water will remain equal to one-third of the ſpirit; and if we ſuſpend another mortar inverted over the firſt, a quantity will remain equal to one-half; and that by other contrivances which ſtill more effectually condenſed the watery vapour, he could obtain a much greater quantity.

I have long been of opinion that a quantity of water might be collected from burning alcohol equal in weight to the alcohol itſelf, or even exceeding it. And this has been found to be fact by ſome experiments ingeniouſly contrived and carefully executed by Mr. Lavoiſier, in which he employed very effectual means for condenſing the watery vapour which ariſes from its flame. He cauſed it to burn very ſlowly, under a tall chimney of thin plate ſurrounded by cold water. By a medium of repeated trials, he obtained nine ounces of water from eight ounces of alcohol burnt in dry air; yet the air

unavoidably carried off with it a very ſenſible portion of moiſture. *(See his Eſſays).*

Some part of this water was undoubtedly preſent in the alcohol before it was inflamed; for it is extremely difficult, and perhaps impracticable, to ſeparate from it completely the whole of the water in which it is originally diluted. But as we get more of the water than there was of the alcohol, it is evident that the whole of this water could not be contained in it. Mr. Lavoiſier, therefore, has accounted for the origin of it in another way, by ſuppoſing that alcohol contains a great quantity of hydrogen in its compoſition, and that the atmoſpheric oxygen combines with this by inflammation, and thus produces water. This ſuppoſition is founded on very ſatisfactory experiments, the firſt of which were made by Dr. Prieſtley, who publiſhed an account of them without attempting to build any theory upon them. And Mr. Lavoiſier immediately afterwards repeated them with the greateſt accuracy.

They were made by forcing the vapour of alcohol to paſs through a red hot tube of metal or earthen ware. The greateſt part of the alcohol was thus changed into hydrogen gas or inflammable air, the bulk of which, on account of the rarity of that ſort of gas, was aſtoniſhingly great, when compared with the bulk of the alcohol; for in the alcohol, it is not in the form of hydrogen gas, which is a compound of hydrogen and latent heat. It is in the denſe form of hydrogen, deſtitute of that latent heat, and this, together with a ſmall portion of carbon, makes up almoſt the whole of the alcohol; for it appears to contain, beſides theſe two, a very ſmall quantity only of ſome other principles; ſuch as a very little oxygen, and perhaps of azote. The preſence of the carbon is known by a ſmall quantity of very light charcoal which it leaves in the red hot tube, and a part of which is diſſolved in the hydrogen gas. And the preſence of the oxygen is proved by a ſmall quantity of carbonic acid gas, which is found mixed with the inflammable air.

Mr. Lavoiſier, therefore, is of opinion that the greater part of the water which ariſes in vapour from burning alcohol is formed by the union of the hydrogen with the oxygen of the atmoſphere, which contributes to its inflammation. This opinion appears to be very well founded.

Beſides theſe ultimate principles which have been found in the compoſition of alcohol, we can extract from it, by ſome leſs deſtructive proceſſes, a ſmall quantity of vegetable acid, ſimilar to vinegar or the acetous acid, and we can even convert a great part of it into that acid, by diluting it largely with water, and making it undergo a particular fermentation, to be deſcribed hereafter. But this is not ſurpriſing, as the acetous acid itſelf is now known to be compoſed of oxygen, combined in a particular and looſe manner with carbon, and with a ſmall portion of hydrogen. The ſmall quantity of acetous acid, which is often concealed in alcohol, is loſt however when the alcohol is conſumed by inflammation. In paſſing through the outſide of the flame where the heat is produced, it is burnt and deſtroyed, together with the carbon, and is changed by the oxygen of the atmoſpherical air into carbonic acid gas, and a ſmall quantity of water. *(See Note* 12. *at the end of the Volume.)*

This may ſuffice for a general account of the nature of alcohol, and of the manner in which it is affected by heat. We muſt next conſider its properties in mixture with other bodies.—

One of theſe properties, which appears remarkable when we conſider this fluid as an inflammable body, is its mixing ſo readily and completely with water in any proportion, which no other inflammable ſubſtance will do. It even ſhews a conſiderable attraction for water. When I have prepared alcohol of an extraordinary ſtrength, I found it was difficult to preſerve it in that ſtate. It attracted humidity even through the corks of the bottles. This ſhews a very ſtrong attraction between this fluid and water. And this attraction further appears by the readineſs with which theſe two fluids will depoſit other ſubſtances

that they may unite together. Moſt of the compound ſalts may be precipitated more or leſs from water by the admixture of alcohol. And alcohol, which can diſſolve a variety of oils and reſinous ſubſtances not ſoluble in water, deſerts or depoſits theſe to unite with water.

The union of alcohol with water, in equal weights, produces eight or ten degrees increaſe of temperature; and the bulk of the mixture is leſs than that of the ingredients by one part in thirty-four.

It is this attraction which renders it ſo difficult to make alcohol very ſtrong by diſtillation alone, although the alcohol in its ſeparate ſtate is much more volatile than water,

Among the ſaline ſubſtances, there are a number that act one way or other upon alcohol. We have already noticed one property of the common vegetable fixed alkali with reſpect to this fluid, that of attracting the water from it when weak, and therefore aſſiſting us to make it ſtrong. And I obſerved, that if much alkali be employed in this way, a ſmall part is diſſolved, and gives the alcohol a yellow colour and diſagreeable taſte, which can only be removed by diſtilling it ſlowly, until a ſmall quantity only remains in the ſtill. I muſt now add, that alcohol thus tinctured with fixed alkali has been eſteemed a more powerful ſolvent of ſome ſubjects than a purer alcohol would be; and hence the chemiſts ſome time ago took much pains to learn the beſt manner of preparing it, or the way to have it as ſtrong of the alkali as poſſible,—and they called it *tartarized ſpirit of wine*. You will find that Dr. Boerhaave gave much attention to the combination of ſpirit of wine with alkali, and conſidered the preparing of a good tartarized ſpirit of wine as a nice and difficult operation. He recommends or enjoins attention to two particulars: 1*ſt*, To uſe the ſtrongeſt or pureſt alcohol; 2*dly*, To uſe alkali of tartar well calcined, and put into the alcohol perfectly dry and hot. If there be the leaſt moiſture in the ſalt, or water in the alcohol, it will be impoſſible to diſſolve the proper quantity of alkali. But I muſt add, that Dr. Boerhaave met with ſo much difficulty, in conſequence of his uſing

the alkali combined with carbonic acid, or in its ordinary ſtate, as we find it in pearl-aſhes or alkali of tartar; that ſtate of alkaline ſalts being ſuppoſed at that time to be their pureſt ſtate, which it is not in reality, the cauſtic ſtate of alkalis being the pureſt. If we take an alkali that is perfectly cauſtic, or totally deprived of its carbonic acid, we can diſſolve as much of it as we pleaſe in ſpirit of wine, weak or ſtrong, or though the alkali itſelf be not very dry. This property I diſcovered in the cauſtic alkali; and it is a conſequence of its being more ſoluble, and its having a greater attraction for other bodies than mild alkali has. It unites with alcohol, as we have ſeen it unite with other inflammable ſubſtances.

Thus we have an eaſy method for making a tartarized ſpirit of wine, as it was called, as ſtrong of the alkali as we pleaſe, which Dr. Boerhaave thought to be ſuch a difficult buſineſs.

As the effects produced with alcohol by a fixed alkali, perfectly pure, are different from thoſe produced by the ſame alkali in its ordinary ſtate, ſo, on the other hand, are they very different, if we take the ſame alkali perfectly ſaturated with carbonic acid. If alcohol be ſuddenly poured upon a ſpirit of ſal ammoniac, formed by diſſolving as much as poſſible of the cryſtallized volatile alkali in water, the alcohol ſeparates the ſalt from the water, forming a thick, and ſometimes firm coagulum, called the *offa Helmontii alba.* It is a cryſtalline ſponge, containing ardent ſpirits.

We ſhall now turn our attention to the mixing of this fluid with the different acids, taking them in their uſual order: The ſulphuric therefore in the firſt place.—

This acid is known to act powerfully on the inflammable bodies in general; and it accordingly unites with alcohol rapidly and violently. It will be proper to pour in the acid at one ſide of the retort, by little at a time, that it may ſlide down under the alcohol; and after each addition, to agitate the mixture with a circular motion. Thus we temper the very great heat produced by the mixture. Equal weights

may be thus mixed by cautious agitation with interruptions; but in whatever way we proceed, a violent commotion is excited, and a heat which the hand could not bear. A thin glaſs muſt therefore be uſed; for if we were to proceed ſo ſlowly that the heat ſhould never be conſiderable, we ſhould loſe much of the valuable product of the operation. Each of the firſt additions of ſpirits produces a puff of ebullition, but this becomes moderate by the time that two-thirds of the ſpirit have been mixed, and the mixture now requires ſomewhat greater heat to make it boil.

This mixture has not a little engaged the attention of the chemiſts, on account of ſome remarkable productions which are got from it when it is diſtilled. A condenſing apparatus muſt be immediately fitted to the retort, and this muſt be immediately ſet upon hot ſand for diſtillation. This may be carried on at firſt with a pretty briſk heat. But this muſt be quickly diminiſhed, when a certain ſign (to be mentioned preſently) appears, or when the liquor in the receiver is reduced to nearly one-half of the alcohol.

The diſtillation produces as follows:

1*mo*, There is condenſed a clear liquor, of a penetrating diffuſive aromatic odour, the quantity of which is equal to half the ſpirit of wine employed.

2*do*, Sulphurous acid and *oleum vini dulce* then come over. But to have theſe without danger, the heat muſt be gentle, and long continued; if otherwiſe, the matter boils over, and the hot froth cracks the top of the retort.

3*tio*, A thick bituminous matter or coal is left in the retort.

But the fragrant fluid which comes firſt, called ÆTHER, is the deſirable product of this diſtillation, and the one on account of which it is commonly performed. It owes its fragrancy to a ſubtile and volatile oily fluid, which makes up the greater part of it, and which was formerly called the *vitriolic æther*, but now the *ſulphuric*. As it is the principal

product of the operation, I ſhall point out the beſt method of managing the proceſs to obtain it in quantity, and perfect.

Firſt, of the different proportions in which the acid and alcohol may be mixed together. The proportion of equal weights is the beſt for producing the greateſt yield of æther from the ſame quantity of the materials. If more alcohol be taken, a great part of it riſes unchanged. If a larger proportion of acid is uſed, the mixture ſoon becomes black and thick, and forms ſulphurous acid.

The chemiſts are indebted to Mr. Beaumè for having inveſtigated the beſt manner of conducting this operation. He tried many different proportions, and found that the one we have taken was the beſt. You may ſee an account of his experiments in his little volume on æthers.

In the conduct of the diſtillation, it was formerly the practice to apply a gentle heat, and diſtil ſlowly from the beginning to the end. It is, however, quite unneceſſary to be ſo cautious at firſt; we may diſtil briſkly in the beginning, and until the æther has diſtilled over. But then, indeed, it is abſolutely neceſſary to diminiſh the heat greatly; and the beſt way to do this is by removing the retort from the hot ſand, and thus putting a ſudden ſtop to the diſtillation. If we neglect to do this, the ſulphurous acid begins to be produced ſo ſuddenly and abundantly, that it makes the matter in the retort boil over in the form of a black foam, blows up the veſſels, and poiſons the whole air of the houſe with an inſupportable and ſuffocating ſtench.

The ſigns by which we may know when it is time to ſtop, that we may avoid this accident, are theſe—

It is time to ſtop when a quantity has diſtilled equal to one-half of the alcohol, or a little more. This critical period of the operation may be alſo perceived by the appearance of a whitiſh vapour, like a miſt, appearing in the retort. And the bubbles formed in the retort by the boiling of the liquor are more numerous, and remain longer

before they burſt. The odour of the vapours perceived at the luting is alſo leſs fragrant than at the beginning.

Another reaſon for ſtopping is, that after having performed one diſtillation, we may perform a ſecond with the ſame acid, by adding to the retort a quantity of freſh alcohol, equal in meaſure to the fluid that was diſtilled off, and then proceeding as before, we obtain a ſecond product, which is exactly ſimilar to that of the firſt diſtillation. And in the ſame manner, by another freſh doſe of alcohol, and a third diſtillation, we get a third product as good as the two firſt; and this repeatedly a number of times. But after a certain number, ſuppoſe ſix or eight, the acid becomes too weak, and has much leſs effect on the alcohol. In practiſing theſe diſtillations, a little of the acid always paſſes over along with the laſt of the æther, and is intimately blended with it; and as a ſmall quantity of ſpirit of wine comes over in the beginning unchanged, it is always neceſſary to rectify the æther, or re-diſtil it, to have it quite pure.

This ſecond diſtillation is very ſimple, requiring only a very gentle heat, the veſſels to be well luted, and the operation performed with day-light. A ſmall quantity of cauſtic ley is put into the liquor in the retort, to abſorb the volatilized acid, and we muſt ſtop when two-thirds have come over, reſerving the reſt, which ſtill contains æther, to be mixed with the materials for another proceſs. Some prefer the cucurbit for this operation, but the retort anſwers perfectly well. *(See Note 13. at the end of the Volume.)*

It is time now to examine this æther, and attend to the properties of it which have attracted notice.—

Firſt, it is called an oily liquor, being a liquor which does not mix with water, except in ſmall proportion. It was once repreſented as not mixable at all with water; but Monſ. Lauragais has ſhewn that this was a miſtake, and that water will diſſolve one-tenth part of its bulk of æther, but no more. I knew this, and had been long in the uſe of mixing it with water, to give as a medicine.

Along with this oily nature, it is the lighteſt of all fluids, and of great volatility. Its ſpecific gravity is about 0,735. A little of it poured out very quickly, evaporates, and ſpreads its flavour generally through the whole houſe in which the bottle is opened. A few drops from the height of the arm will ſeldom reach the floor. As it evaporates very faſt in the ſpontaneous way, ſo alſo it very ſoon arrives at a boiling heat. It boils at about 100° of Fahrenheit, even under the preſſure of the air. And when we examine its proper boiling point, by removing the preſſure of the air, we find it as much lower than thoſe of other fluids in the ſame circumſtances, and far below the freezing point of water. *(See Note* 14. *at the end of the Volume.)*

Cold is produced alſo by the ſpontaneous evaporation of æther. Beaumè made Reaumur's thermometer deſcend below froſt with cloths wet with æther, and wrapped round the phial.

Another quality for which æther is eminent, is inflammability. It is very liable to catch fire by the mere approach of a candle while we pour it from one veſſel into another. Therefore, as it cannot always be fully condenſed, the operation for æther ought always to be performed in day light.

It is an uſual experiment by itinerant ſhowmen to throw a lump of ſugar, ſoaked in æther, into a glaſs of warm water. When a candle is applied to the ſurface of the water, it catches fire, and burns in a very amuſing fluttering manner. The heat of the water expels the æther in a ſtream of bubbles, which take fire at the top of the water. The glaſs muſt be deep and narrow, that the ſucceſſion of bubbles may eſcape near enough to ſet each other on fire.

Æther burns with a remarkably bright flame, frequently emitting ſparks more brilliant than the reſt, and produces a ſenſible ſoot.

The remaining properties of this fluid are chiefly thoſe of a ſolvent of many ſubſtances. It diſſolves a number of reſins, gums, &c. as we ſhall learn afterwards more particularly.

The medical qualities of this ſingular ſubſtance are alſo eminent,

and deſerve our notice. Internally taken in water, in the quantity of 10, 20, 30, or 40 drops, it is a powerful antiſpaſmodic. But its effects as an external application are the moſt remarkable. Applied to the forehead in the palm of the hand, it performs all the wonders of Dr. Ward's volatile eſſence, in reſolving ſpaſms and removing nervous pains in a moment, as it were by charm. Toothache and headache commonly yield to it. I am inclined to think that it acts in ſuch caſes by a ſort of revulſion. It brings on, in a moment, heat and inflammation upon the ſkin, which, to ſome, become inſupportable. But it goes off immediately when the hand is removed. It brings on this ſuperficial inflammation more quickly than any bliſter, ſinapiſm, or ſuch application; and it is much more under command,—for as ſoon as the hand is removed from the part, the heat and uneaſineſs abate, and ſoon go off entirely. I am therefore perſuaded that it is very proper in may caſes in which it has not been thought of, as in pleuritic ſtitches, rheumatic pains, and other ſuch caſes, in which bliſtering and cupping are of ſervice. There are many ſuch caſes, in which it is expedient to apply remedies of quick operation. Rectified æther ſhould be uſed.

Of the effects of mixing alcohol with the nitric acid, chemiſtry furniſhes many examples, which are remarkable, both for the appearances which they exhibit, and the information that we derive from them.

This acid, when obtained from nitre by the proceſs formerly deſcribed, and which has the name of *Glauber's ſmoking ſpirit of nitre*, and was thought the ſtrongeſt and pureſt, is in fact the weakeſt as an acid, and impure. It is a mixture of two acids, now diſtinguiſhed by the name of NITRIC and NITROUS. The Latin names expreſs their diſtinction more preciſely, *nitroſum* denoting an abundance of that which diſtinguiſhes it as nitrous, viz. the fiery colour, and copious deep blood-coloured fumes, and offenſive ſuffocating ſmell. The *nitric*, on the other hand, is colourleſs, and emits no ſenſible fumes. Yet, in all the diſtinguiſhing properties of an acid, it exceeds the other,

having a much ſtronger attraction for water, alkali, and every thing that is diſſolved by it; nay, even for that which ſeemed to characteriſe the excellency of the other,—I mean for inflammable ſubſtances. It acts on all ſubſtances much more violently than the nitrous, diſſolves more alkali, earth, or metal, or even inflammable ſubſtance; and its virtues are permanent, whereas the red fumes of the nitrous acid waſte by expoſure, and the acid becomes unable to diſſolve the ſame quantity of alkali as before. It was long ſuſpected, therefore, that Glauber's ſpirit of nitre was a compound, and that it contained inflammable matter combined with it, ariſing from impurities in the nitre employed in the proceſs for obtaining it. This ſuſpicion was confirmed by obſerving that ſmall additions of the more inflammable ſubſtances to the colourleſs acid immediately produced that fiery colour, and thoſe red fumes, for which Glauber's ſpirit of nitre is remarkable.

I was the firſt, I believe, who entertained a notion ſomewhat diſtinct on this ſubject. Finding that Glauber's ſpirit of nitre, when diſtilled to about two-thirds of its bulk, had loſt entirely its fuming quality, and that the liquor which came over poſſeſſed it more eminently, while the firſt was ſtronger as an acid, I was led to conſider the original liquor as a mixture of two ſeparable ſubſtances, of which that was the compound which exhibited the weakeſt action on the ſubſtances which are diſſolved by both. This I conceived to be conformable to the general facts in chemiſtry.

I was therefore diſpoſed to conſider Glauber's ſpirit of nitre as a compound of the acid of nitre and inflammable matter, or perhaps of the principle of inflammability. With this view of the ſubject, I tried to form anew this fuming ſpirit of nitre, by adding to the pale ſpirit of nitre a ſmall quantity of alcohol, which I conſidered as an inflammable ſubſtance ſufficiently ſimple not to contaminate the new compound with unſuitable ingredients: And I ſucceeded quite to my wiſh. A very minute portion of alcohol being added to a quantity of the

pale and very ſtrong acid of nitre, from which I had ſeparated the highly fuming acid by diſtillation, immediately imparted to it the fiery colour and blood red fumes, and made it in all reſpects ſimilar to Glauber's fuming ſpirit of nitre, having all its properties. This was, I think, in the year 1760.

This experiment being very inſtructive, it will not be amiſs that I tell you the method of making it in the neateſt and moſt perſpicuous manner. Take a glaſs tube, about one-tenth of an inch in diameter, and draw one end of it more ſlender. Having put the acid into a ſolution glaſs, dip the ſmall end of the tube five or ſix inches into ſpirit of wine, and then, cloſing the top of it with the finger, take up the ſpirit with it, and dip it to the bottom of the nitrous acid. Then, taking off the finger, let ſome (about half an inch) of the ſpirit run out of the pipe into the acid, and then ſtop the pipe again. You will ſee the union take place immediately, and ſmall bubbles form on the mixture, few of which will reach the top;—the whole will acquire an orange colour. Purſuing this method, you will ſee the progreſſive alteration very diſtinctly. One of my ſtudents, at Glaſgow, aſked me, after lecture, whether inflammable air would anſwer the ſame purpoſe, ſeeing that ſome imagined it to be the principle of inflammability. The thought pleaſed me, and I tried it with perfect ſucceſs. It produced the ſame effects, but required an immenſe quantity, which did not ſurpriſe me, by reaſon of its great rarity.

But this mixture of nitric acid and alcohol merits further attention. I found that, by gradually adding more alcohol, the volatility of the acid, or a diſpoſition to emit red fumes, increaſed, and the attraction for water, and its acidity, diminiſhed; and that, by proceeding in this manner, the acid may be totally diſſipated in thoſe offenſive fumes, leaving only acidulated water, having no inflammability, nor the ſmell of nitrous acid, but rather that of vinegar, which it alſo reſembles in taſte and in its mixture with other ſubſtances.

This proceſs is accompanied with great heats, notwithſtanding the

copious eruption of theſe fumes; and it is very hazardous, becauſe every addition produces a great and ſudden increaſe of heat, which contributes to increaſe the exploſive power of the mixture, and will throw it about the room, while the veſſels run the riſk of ſplitting by the ſudden changes of temperature. To ſucceed to the degree I have mentioned requires a very long time, mixing very ſmall portions of alcohol at once, and keeping both ingredients in veſſels ſurrounded with ice and water. It will often be obſerved, that, after alcohol, amounting to one-fourth of the weight of the acid, has been added, the exploſions are colourleſs and tranſparent, and are accompanied with a fragrant ſmell, reſembling that of vitriolic æther. This indicated the production of ſomething different from the nauſeous blood red fumes, and gave the chemiſts hopes of obtaining an ætherous fluid, different from the vitriolic.

They were better conducted to this by another mixture, well known in pharmacy,—the preparation for obtaining what is called DULCIFIED SPIRIT OF NITRE. This is prepared by cautiouſly mixing with rectified ſpirit of wine, one-fifth or one-fourth of its weight of ſtrong nitric acid, and diſtilling the mixture. It produces a liquor with no remarkable acidity, having a fragrant ſmell, much reſembling that of apples. This encouraged to a farther puſhing the addition of acid to the alcohol. Their mutual action was incomparably more quiet and manageable. For, as it already appears that a very ſmall quantity of alcohol gives this ungovernable volatility to a great deal of the acid, it is plain that, ſince a ſmall quantity of acid is not converted at once into incoercible ſteams by mixing with a great proportion of alcohol, repeated additions of ſuch ſmall quantities, after the heat and ebullition produced by the preceding addition have ceaſed, muſt in all probability be quiet and ſafe. So the caſe turns out; but ſtill, although the ſucceſſive mixtures go on without much trouble, it is found that when ſomething more than one-third of acid (by weight) has been added, the mixture begins to explode and become troubleſome; and,

if one-half be added, it is almoſt unmanageable. Mr. Navier, a French phyſician, was the firſt, I believe, who publiſhed a practicable and ſucceſsful proceſs, founded, I preſume, on ſimilar obſervations. He preſcribes the cautious and gradual mixture of one-half of acid with the alcohol, in a very ſtrong glaſs veſſel, which he immediately corks up, and ſecures the cork with leather, tied hard over it, and ſecured by packthread; and the bottle is kept in cold water. Thus are the elaſtic ſteams prevented from forming, by the great preſſure produced by thoſe already generated. The fluids gradually act on each other, and an æther is produced, which, like the vitriolic, floats a-top. As all this goes on under a very great preſſure, it is plain that if we pull out the cork, or even untie the packthread, the elaſtic exploſion will take place in an inſtant, through the whole liquor, and it would be thrown out. Mr. Navier, therefore, directs the cork to be pierced with a pin, and the vapour allowed to eſcape. After this, the æther may be ſeparated by a funnel. It amounted to one-third, or one-half of the alcohol.

This proceſs was ſtill hazardous, for the bottle often burſt. Mr. Beaumé, of the French Academy of Sciences, improved this proceſs, by carefully inveſtigating the beſt proportion and manipulation. He found that two parts of acid to three of ſpirits gave the greateſt produce of æther from the ſame alcohol, and directed both ingredients to be uſed in the coldeſt ſtate, by keeping each in melting ice, or water and ice, and by ſetting the corked-up bottle in the ſame ſituation. This proportion of ingredients ſecures us againſt the chance of exploſions wholly ungovernable, and the low temperature greatly moderates the action that is unavoidable. He alſo directs us to give the liquor in the bottle a briſk whirling motion immediately before pouring in any more acid. This prevents any accumulation in a particular ſpot.

By this proceſs we obtain, in three or four hours, a conſiderable quantity of æther, which is obſerved to form in little drops all over the liquor, and riſe gently to the top. By allowing the bottle to remain undiſturbed for eight or ten days we obtain about half the

weight of the alcohol, after which no more is produced in theſe circumſtances.

I am by no means certain that this proceſs will give the greateſt product. I ſuſpect that the external preſſure really prevents the chemical union, in the ſame manner as it certainly prevents it in the boiling of water. That it is prevented in this inſtance is evident, becauſe heat is not abſorbed unleſs the preſſure be removed. Therefore the heat is not combined when vapour is not produced. The like may happen here. I am juſtified in this, from obſerving that more nitric æther is obtained by other artificial proceſſes, in which this preſſure does not take place. I ſhall mention one, which I practiſed before I heard of thoſe of Navier and Beaumé, and is extremely ſimple and eaſy.

Into a ſtrong phial, having a ground ſtopper, I firſt pour four ounces of ſtrong pale nitric acid. I then add three ounces of water, pouring it in ſo gently that it ſwims on the ſurface of the acid. I then pour in, after the ſame manner, ſix ounces of alcohol. I put in the ſtopper ſlightly, and I ſet the phial in a tub of water and ice. The acid mixes ſlowly with the water, and, in a diluted ſtate, comes in contact with the alcohol, on which it immediately acts, and æther is produced ſlowly and quietly. The liquor gets a dim appearance, becauſe imperceptible bubbles are formed, which get to the top, and having collected to a certain degree, they lift the ſtopper and eſcape. After eight or ten days, I find upwards of three ounces of nitric æther, though I am certain, by the ſmell, that much eſcapes with the vapour. This is, however, a certain, eaſy, and ſafe proceſs, though it is ſlow and imperfect.

More artificial proceſſes have been followed by ſeveral eminent chemiſts.

1. Mr. Woulfe's, in his general manner of managing all diſtillations where fumes of difficult condenſation are produced. He uſes a ſucceſſion of receivers, which are tubulated. A tube goes from

the top of the firſt into the ſecond, down to the bottom, and another from the top of the ſecond into the third, and ſo on. By this contrivance, what is not condenſed in the firſt receiver is condenſed in the liquor of the ſecond, &c. A mixture of equal parts of ſtrong acid and alcohol is thus diſtilled with a very moderate heat, and a good produce of æther is obtained.

2. Nitric or nitrous acid is made to act, in the very inſtant of its formation, on alcohol. Nitre is put into a tubulated retort, to which is fitted a receiver. Vitriolic acid is poured on this, and immediately after, ſpirits of wine. The nitrous acid is diſengaged, which riſes through the vitriolic, and acts on the alcohol; and æther is produced, whoſe ſteams are condenſed in the receiver.

3. Inſtead of putting the alcohol upon the vitriolic acid and nitre, it is put into a glaſs veſſel, which communicates, by means of a bent tube, with a large receiver luted to the retort containing the nitre and vitriolic acid. Heat being applied to the retort, the nitrous acid is diſengaged, and part of it is condenſed in the receiver, and part paſſes on to the bottle containing the alcohol, on which the vapours act; and æther is produced without any troubleſome exploſions.

Mr. Chaptal, who prepares a great deal in the way of commerce, uſes two receivers in ſucceſſion, the firſt being ſet in water, and the ſecond covered with wet cloths, and it has a tube proceeding from the top, which is bent downward and immerſed in a bottle of water. He ſays that the proceſs is eaſy and ſure, affording very pure æther, and in good quantity.

But all the proceſſes, and indeed every treatment of nitric acid with alcohol, requires much caution, that we may eſcape accidents.

The reſidue of the diſtillation is acid, much changed in its properties, appearing more like vinegar, or even more reſembling the acid of ſorrel, or of ſugar. It burns to a coal, and produces, by a great

heat in close vessels, carbonic acid, and empyreumatic oils, like all other vegetable substances.

The æther of all the processes here described requires rectification, to clear it of acid and alcohol, which came over with it in the distillations, or mix with it in the processes by digestion. This rectification is performed by distilling it from caustic alkali. This reduces its quantity; for we must not distil more than two-thirds or one-half of the first æther. To bring this to still greater purity, some direct it to be mixed with one-fifth nitrous acid, and distilled again,—taking two-thirds of the product set apart, and rectified from caustic alkali. The rest of what comes over is a less perfect æther,—the *mineral anodyne liquor of Hoffmann;* and the remainder in the retort is a *dulcified spirit of nitre.*

Pure nitrous æther greatly resembles the vitriolic in lightness, inflammability, and flavour. This last quality, indeed, is inferior to the vitriolic, being stronger, and somewhat pungent; the taste is also more acrid; the colour inclines considerably to yellow; it burns with a brighter flame than the vitriolic, and produces more smoke, and leaves a stain in the dish. When kept, it is apt from time to time to blow out the cork. This is attributed to æther not yet perfectly formed, and is said never to happen, if the produce be carefully rectified from caustic alkali, and if we do not take too much of what comes over.

The muriatic acid, in its ordinary state, exhibits no disposition to act on alcohol, or any other inflammable substance. But the chemists, curious after a knowledge of this new discovered fluid, the æther, were eager to compose one by this acid also, although their then received theories gave them little encouragement to expect it. Many attempts, however, were made, but long without success.

The simple mixture and distillation of the muriatic acid and alcohol has no effect. The mixture is indeed called the *dulcified muriatic acid,* but there seems no combination or change of properties. Nor

has better ſucceſs followed the attempts to combine them in the inſtant of the production of the acid, or by uniting their vapours. At laſt, methods were diſcovered, in which, by employing the acid in a compound and peculiar ſtate, a combination took place, and muriatic æther was produced. Of ſome of thoſe methods I ſhall give you a ſhort account.

I. The Marquis de Courtanvaux mixed alcohol with a liquor called *the ſmoking liquor of Libavius*. This, as you will learn afterwards, conſiſts of muriatic acid ſurcharged with oxygen, and united with tin. Alcohol, being mixed with twice its weight of this liquor in a retort produced heat and white ſuffocating vapours, but accompanied with an agreeable ſmell. When diſtilled, we firſt obtain a ſtronger alcohol, and then the æther appears, indicated by the ſmell, and by trickling down the ſides of the receiver. After ſome time, the ſmell becomes ſuffocating,—the receiver muſt now be removed, otherwiſe the æther will be tainted with many products, ſuch as acid, oil, a ſubſtance like butter, &c. which you will underſtand afterwards.

The æther thus obtained muſt be rectified from cauſtic alkali, and only half of what comes over muſt be taken.

II. Similar to this is the proceſs of the Baron de Born. He uſes a compound of muriatic acid and the flowers of zinc. (*Mem. des Scavans Etrangers*, VI.) The acid obtained from twelve pounds of ſea ſalt, being ſaturated with the flowers of zinc completely diſſolved, the ſolution is evaporated till of the conſiſtence of greaſe. This is mixed very gradually with ſix pounds of alcohol, and after digeſting the mixture eight days, and filtrating it, the clear liquor is diſtilled, beginning with a very gentle heat. We obtain,

1. Water, amounting to almoſt half of the ſpirits.

2. An aromatic ſpirit of wine,—the matter in the retort now grows thick like melted wax.

3. Æther.—When this has all paſſed, the matter in the retort is dry, and the heat muſt be increaſed.

4. A ſweet oil like eſſence of lemon. This will ſwim on the æther, and is the laſt volatile product.

Great care muſt be taken that the heat be not too great before the matter in the retort becomes dry; for it is apt to burſt up in ſudden clammy bubbles, which touching the colder parts of the retort, will ſplit it.

The æther muſt be rectified from the aromatic ſpirit, by the gentleſt heat of a lamp furnace; and the ſpirit which remains may be poured back on the reſiduum in the firſt retort, and more æther, &c. obtained, in the manner practiſed for vitriolic æther, without end.

The author obtained by this proceſs two pounds of æther, and four ounces of the ſweet oil, both of which were remarkably fragrant.

III. Mr. Woulfe made muriatic æther by cauſing the vapour of boiling alcohol to meet with the muriatic acid gas, as it was diſengaged from ſea ſalt, in a glaſs veſſel, from which a ſyphon tube proceeded into another glaſs containing alcohol. The tube reached almoſt to the bottom of the alcohol, and the vapours which did not condenſe here eſcaped, and went by another glaſs tube into a ſecond veſſel containing alcohol, and what was not condenſed there went into a third, and ſo on. By this management the union was effected, and æther obtained in each of thoſe veſſels, ſwimming on the alcohol. Theſe portions were mixed and rectified by diſtillation with a gentle heat, from cauſtic alkali, being much contaminated with acid vapours. The whole proceſs was extremely tedious and troubleſome, requiring ſeveral cohobations, or returning the liquors back again upon the reſiduum, before a tolerable quantity of æther was obtained. The veſſels of alcohol were heated to a great degree by condenſing the vapours, and ſoon gave over condenſing. *(See Phil. Tranſ.* 1767.)

IV. A Mr. Schroeter of Berlin prepared a muriatic æther by diſtilling from a mixture of eight parts of ſea ſalt, four of ſulphuric acid, four of black manganeſe, (a ſubſtance containing much oxygen), and three of alcohol. In this proceſs, the muriatic acid was diſengaged

from the ſea ſalt by the ſulphuric, and, in its naſcent ſtate, acted on the alcohol, being aſſiſted by the manganeſe (without which we know that it will not ſucceed) in ſuch a way as to produce abundance of æther. Mr. Pelletier of Paris, by a ſimilar proceſs, obtained four ounces of æther from eight of alcohol. The manganeſe evidently appears to favour the production of æther exceedingly. If the ordinary muriatic acid be diſtilled from manganeſe, its properties are remarkably changed; and if employed in this ſtate in Woulfe's manner, it produces æther with great facility. There is, therefore, ſomething which it poſſeſſes, in this ſtate, and in thoſe of the muriats of tin and of zinc, that is ſimilar, and which fits it for this preparation. This change on the muriatic acid will be minutely conſidered in due time.

The æther obtained by any of theſe proceſſes, when pure, is like the other two, immiſcible with water except in a ſmall degree, extremely light, highly odorous and penetrating, but much more offenſive to the lungs than they are. It is highly inflammable, and in burning has much ſmoke, and emits a ſmell as penetrating as ſulphuric acid. It is leſs agreeable to the taſte, having the ſtyptic taſte of alum.

Thus we ſee that the three principal acids have in one reſpect a ſimilarity in their action upon vinous ſpirits. Even the muriatic, which, in its ordinary ſtate, ſhews no action on inflammable ſubſtances in general, or this one in particular, can be put into ſuch a ſtate, competent to it as an acid, which enables it to contract an union with alcohol, or produce a change on it, ſimilar even to that produced by the nitric, which acts the moſt violently of all on them. This muſt be conſidered as a common property of the acids, which it behoves the chemical philoſopher to inveſtigate in his own way. A chemiſt is diſpoſed to aſcribe it to ſome ingredient common to the acids, and we are intereſted to diſcover what this may be.

This may be conſidered as giving a theory of æthers, or an explanation how they are produced. They were diſcovered at a time when

chemical ſcience had made conſiderable progreſs, and its cultivators were eager to give a rational account of the many ſurpriſing effects or changes which it preſents to our view. Therefore attempts were ſoon made to explain all theſe appearances.

One of the firſt who attempted this was Mr. Macquer. He imagined that the production of theſe light oily fluids was nothing but an abſtraction of water from the ardent ſpirits, and that this was effected by the ſtrong attraction for water, which is a diſtinguiſhing property of all the acids. By this abſtraction of water, he conceived the alcohol to be reduced to its ſtate of purity; and this he thought was a compound of a ſubtile oily principle and water ſtrongly combined, and which, by the preſence and quantity of the water in its compoſition, becomes miſcible with water in any proportion. The acids, by their ſtrong attraction of water, rob the ſpirit of a part of its elementary conſtitution, rendering it more inflammable and oily, and no longer ſo miſcible with water, but more volatile and inflammable.

But this theory is inſufficient for explaining the phenomena. It is incongruous with the general train of chemical facts, that depriving ardent ſpirit of water will diminiſh its attraction for it. And it is not fact that the acids which have the ſtrongeſt attraction for water are the moſt effectual for changing alcohol into æther. Acetous acid, which has a weak attraction for water, produces more æther from a quantity of alcohol than the foſſil acids do; and the muriatic acid, which attracts water with great force, produces æther with great difficulty, eſpecially when employed in that ſtate in which it attracts water moſt ſtrongly. It ſhould alſo be a conſequence of Mr. Macquer's theory, that all æthers ſhould be alike, which is very far from being the caſe.

Mr. Berthollet, a chemiſt of the firſt eminence, thinks that all the æthers are formed merely by the addition of more oxygen to the compoſition of the alcohol. This opinion ſeems chiefly founded on the neceſſity of employing acids, which abound in oxygen, and on the

phenomena and conſequences of ſome of thoſe proceſſes, which ſhew the acid to be very much deoxygenated.

But I confeſs that I view the formation of the æther in a different light. When the proceſſes are conducted in the beſt manner, we have no appearance of deoxygenating the acid during the formation of the æther. The ſulphurous acid does not appear till all the æther has paſſed over. And we obtain the greateſt quantity of nitrous æther, when we ſucceed beſt in preventing the exploſion and the deoxygenation of the acid. When we neglect the precautions for preventing this, ſuch as the keeping the mixture very cold, and making the additions very gradually, we have red fumes, indicating the deoxygenation of the acid, and we obtain leſs æther.

I am perſuaded that the æthers are compounds of the alcohol with a greater or leſs portion of the acid employed. The acids which are moſt abundant in oxygen are the fitteſt, for this reaſon, that they have the ſtrongeſt action on alcohol and other inflammable ſubſtances. I believe that the acid is combined with the alcohol, ſo as to be neutralized by it, while the attraction of the alcohol for water is diminiſhed, for the ſame reaſon, and in the ſame manner, as the attraction of both acids and alkalis for water and other ſubſtances is diminiſhed when they are combined in forming a neutral ſalt. The alcohol, therefore, aſſumes that immiſcible and oily nature which is obſerved in it. That an oily appearance and conſiſtency may be produced and increaſed in this way, is evident from the example of the *oleum vitrioli dulce*, which has more the appearance of an oil than the æther itſelf. Yet it is only æther ſuper-ſaturated with acid. The æther is totally convertible into this oil by repeated diſtillation with the acid; ſo is alſo the nitrous æther. The preſence of an acid in the moſt perfect æthers has been proved by Crell and Scheele. Both of theſe chemiſts have ſubſtituted one acid for another in the ſame æther, ſo as to change one æther into another, in a certain order. Were pure oxygen all

that is united with the alcohol in forming æther, all acids would be indifferent, and all æthers alike *.

Mr. Lavoiſier has been the moſt ſucceſsful in explaining many phenomena in the action of the acids on alcohol and ſimilar ſubſtances, and has made many judicious, accurate, and inſtructive experiments with this view. His explanations are founded on a careful analyſis of the ultimate conſtituent principles of alcohol, and of the vegetable ſubſtances from which it is produced.

Mr. Lavoiſier's opinion was, that the vegetable ſubſtances in general, and thoſe ſuſceptible of fermentation, ſuch as ſugar, mucilage, farina, and the like, are compoſed of carbon, hydrogen, and ſome oxygen, looſely joined, and in various proportions. By receiving more of the oxygen from the nitric acid, when it acts on them, or from the air, in the acetous fermentation, they are changed into vinegar, or ſome other acid. When the nitric acid is made to act violently, it produces efferveſcence and elaſtic matter: 1. By the changes which the nitric acid undergoes into *acidum nitroſum*, or into nitrous air, according to the degree of deoxygenation; 2. By the change of part of the carbon into carbonic acid gas, in conſequence of its cloſe union with part of the oxygen of the nitric acid.

Alcohol is compoſed of the ſame principles which compoſe theſe vegetable fermentable ſubſtances. But the principles are combined in the alcohol in different proportions from thoſe which conſtitute ſugar, and the reſt of them. In alcohol there is a leſs proportion of oxygen to the others, eſpecially to the hydrogen. In conſequence of this it is more inflammable and volatile than thoſe other vegetable productions.

The carbonaceous matter in alcohol is clearly exhibited in the experiment of Prieſtley and Lavoiſier formerly mentioned, where the

* Do not the more brilliant flame, and the ſmoke and ſoot, indicate a redundancy in the carbon rather than in the oxygen?

EDITOR.

vapour of alcohol was made to paſs through a red hot tube. It alſo preſents itſelf in the proceſs for ſulphuric æther, by imparting a black colour to the acid in the retort, in proportion as the æther forms, and oxygen is abſtracted from part of the acid. Its place is ſupplied by the carbon expelled from the alcohol by this elective attraction. At laſt, the matter in the retort becomes coaly, and a conſiderable quantity of very fine charcoal is elevated. It is probably thus partly retained and ſeparated from the other elements of the alcohol, by the ſtrong attraction of the ſulphuric acid, which, when the diſtillation is too long continued, is imperfectly decompounded by it, and changed into ſulphurous acid; and the vapours of this volatile ſulphurous acid, in conjunction with the carbonic acid gas, into which a part of the carbon is changed on this occaſion, explain the violent and ſudden ebullition of the matter in the retort, and burſting of the veſſels, when the diſtillation is puſhed far with too great a heat. And during the formation of nitrous æther, there is always a little effervescence or a production of gas, formed from a part of the carbon changed into carbonic acid by ſome of the oxygen of the nitric acid, which, being thus partly changed into azotic gas, contributes to make up the quantity of the elaſtic gas. And along with theſe gaſes, vapours of the nitrous æther, formed in conſequence of its great volatility, alſo eſcape. The matter of theſe different gaſes, however, can be confined and made to remain combined with the nitrous æther for ſome time; of which we have an example in Mr. Navier's and in Mr. Beaumé's proceſſes for nitrous æther; the ſtrong preſſure to which the materials are ſubjected in the corked bottles repreſſing their volatility,—but whenever the bottle is opened they are ſure to eſcape.

All the æthers therefore, as I ſaid before, appear to be compounds of the alcohol, and of a ſmall portion of the acids made uſe of. A part only, and that very little, of the acid is decompounded, leſs or more, by the loſs of ſome oxygen during the proceſs; and a part only of the carbon is taken from the alcohol. Æthers, therefore, contain

a leſs proportion of this principle, and a larger one of the hydrogen than alcohol does. This idea appears probable, from the lightneſs and volatility of æther, and from the black colour and other appearances of the acid which remains in the retort in the diſtillation to obtain ſulphuric æther.

The experiments you have now ſeen with mixtures of alcohol and nitric acid confirm the character of this acid, which is eminent by a diſpoſition to act violently and powerfully on the inflammable ſubſtances, and others allied to them, which powerful action of it plainly depends on the great quantity of ſeparable and active oxygen which it contains.

Of this we have another eminent example in the action of ſugar and nitric acid on one another.

Some of the qualities of ſugar are ſufficiently known to you, ſuch as its ſolubility in water, and the cryſtals called ſugar-candy which it forms, when the ſolution of it, or ſyrup, is properly cryſtallized. Loaf ſugar is only a maſs of very ſmall cryſtals cohering together, and therefore more readily ſoluble.

Sugar is entirely a vegetable production, and is found in the juices of many vegetables. It is commonly obtained from the juice of one plant, which abounds with it the moſt of any, viz. the ſugar-cane. But many other vegetables, or parts of vegetables, contain ſome ſugar. It is often cryſtallized or concreted in fruits that are dried.

As ſugar is always a vegetable production, not being found in any other part of nature, we may expect to find in it the ſame elementary principles of which vegetables are compoſed, or ſome of thoſe principles. Accordingly, when it is ſubjected to the moſt deſtructive kind of analyſis by fire, it yields a large quantity of hydrogen gas, mixed with carbonic acid, and holding diſſolved a ſmall portion of the carbon not combined with oxygen: But a conſiderable portion of carbon remains behind in the apparatus, in the form of charcoal. From the reſult of this analyſis, it is plain that ſugar is compoſed of carbon, com-

bined with hydrogen and with ſome oxygen at the ſame time. Theſe two laſt ingredients are in their denſe unelaſtic ſtate. And all the three are combined with that weak attraction with which the elements of vegetables are known to cohere.

You can eaſily imagine that ſuch a compound as ſugar may be made to receive a larger quantity of oxygen than that which it naturally contains. And this is found to be true, when we apply to it the nitric acid; but no one can imagine, till he has ſeen it, the violence with which the action goes on. When a bit of loaf ſugar is put into nitric acid, it is ſome time (about three or four minutes) before the combination becomes obſervable. Small bubbles begin to detach themſelves, and immediately on their reaching the ſurface, acquire a deep blood red colour. The liquor becomes warm, and the emiſſion of bubbles becomes more and more copious, till the whole is in violent ebullition, and the upper part of the veſſel is filled with the blood red vapour, which becomes tranſparent; and the production of thoſe red vapours goes on till the ſugar is diſſolved or conſumed, and the liquor acquires the greeniſh colour of freſh made aquafortis.

If this mixture be made by employing common aquafortis, a gentle heat is required, and then the phenomena are nearly the ſame in kind, though in a much more moderate degree. What I chiefly mean to conſider juſt now is the vapours which are produced. They are found to conſiſt of oxygen and azote, the ſame which I have given as the conſtituent parts of the nitrous acid. But they are in a very different proportion, being nearly as 68 to 32, and require a great addition of oxygen to make them equivalent to nitric acid, or even to nitrous acid. When pure, they are not only tranſparent, but as colourleſs as common air, and are perfectly incondenſible by pure water, or ordinary cold. The deep red colour acquired by the fumes ariſes entirely from the mixture with the vital air of the atmoſphere. The gas combines with oxygen, and the two collapſe into nitrous acid. If a glaſs jar, filled with vital air or oxygen, be inverted on water, and ſome of the gas

obtained from ſugar in the way now deſcribed be let up into it through the water, we have an inſtantaneous deep red cloud, and the water riſes to the top of the glaſs, in conſequence of the collapſing of the two gaſes. It contracts no ſuch union with azote or carbonic acid gas. From this account you ſee that it is the fluid called nitrous air, or nitrous gas (as the French call it) which was firſt diſcovered by Dr. Prieſtley, but produced by him by other proceſſes than this. And by making a great number of experiments with it, he made many uſeful, intereſting, and inſtructive diſcoveries. I ſhall ſhew the principal experiments with it ſoon,—when we ſhall have an opportunity for preparing it in a more perfect and pure ſtate than this. I ſhall only remark on it at preſent, that it is the nitric acid changed to a much greater degree from its common ſtate than it is in the acidum nitroſum, and this in conſequence of having loſt a greater proportion of its oxygenous principle: And therefore it has no perceptible acidity; and but little attraction for water. It retains, however, the diſpoſition to unite again readily with oxygen; and in uniting with it, forms firſt the acidum nitroſum, and afterwards, with a larger quantity, the moſt perfect nitric acid.

Theſe are the changes produced in the nitric acid while it and ſugar act on one another.

The ſugar too, as might be expected, undergoes a great change. It totally loſes its ſweetneſs, and is converted into a perfect acid by its union with the oxygen of the nitric acid.

Mr. Bergmann, by diſtilling aquafortis from one-ſixth of its weight of ſugar, obtained a prodigious quantity of the gas juſt now deſcribed, and reduced the ſugar to a pure acid ſalt, called the Acid of Sugar. It cryſtallizes in four-ſided ſpiculæ, terminated by a ridge.

The acid of ſugar expoſed to a heat gradually increaſed to a red heat, firſt effloreſces, loſing its water of cryſtallization, and then becomes brown, and emits compounded vapours, which, by careful treatment, condenſe into the ſame products that are obtained from all

vegetable ſubſtances, or remain in the form of elaſtic gaſes; that is, empyreumatic acid and oil, ſoot, and a great quantity of carbonic acid and inflammable air. Part of the ſalt, however, ſublimes, no way differing from its original form.

When examined in the way of mixture with the ſubſtances which we have already conſidered, it exhibits ſeveral remarkable properties.

With the mineral alkali, it forms a ſalt of difficult ſolution, having an exceſs of alkali in its cryſtals.

With the vegetable alkali, it forms a deliqueſcent ſalt, when perfectly neutral, but which cryſtallizes when either ingredient exceeds in a certain proportion.

With volatile alkali, it forms a ſalt which cryſtallizes in four-ſided priſms. This ſalt is decompoſed in a very ſingular manner by heat, namely, by the deſtruction of its acid, and we obtain very mild volatile alkali, formed by the carbonic acid which ariſes from the deſtruction of the acid. It is worthy of particular remark, that no deflagration appears in treating the acid of ſugar, or its compounds, by great heats, nor is any azote obtained. This ſhews that it does not owe its acidity to its containing nitrous acid, as was ſuppoſed when it was firſt diſcovered.

With lime, it forms a ſalt inſoluble in water (if that name be competent to ſuch a ſubſtance). It is very remarkable that the attraction of this acid for lime exceeds that of the three mineral acids. Lime alſo decompoſes the three ſalts already mentioned. Acid of ſugar, therefore, will detect lime in mineral waters, by taking it from every other ſolvent.

It forms a white powdery ſalt with magneſia, and with barytes, which laſt earth decompoſes the magneſian ſalt.

Acid of ſugar diſſolves in ſulphuric acid, giving it a brown colour.

Nitric acid acts on it, and decompoſes part of it, and we obtain, by diſtillation, vinegar and carbonic acid.

If freſh nitric acid be diſtilled from what remains, we have the ſame products.

When this action of nitric acid and ſugar on one another was firſt diſcovered by Profeſſor Bergmann, it was ſuppoſed that the acid we obtain was a principle or production peculiar to ſugar. It was therefore called the *acid of ſugar*. But by ſimilar experiments, which have ſince been made on a variety of vegetable and animal ſubſtances, ſubjected to the action of the nitric acid, we have learned that the acid acts on them all in a ſimilar manner, that is to ſay, with ſimilar efferveſcence and the production of ſimilar elaſtic fluids, and that many of thoſe ſubſtances are thus changed alſo, at leaſt in part, into an acid exactly ſimilar to that got from ſugar, although they are not at all ſweet, nor appear to contain any ſugar. This happens with the vegetable mucilages and glues, gum arabic, tragacanth, and others; alſo with ſtarch, and the mucilaginous part of lemon juice. Its preſence in this laſt was diſcovered by Scheele; and he evinced its being the mucilaginous part of lemon juice which contained the ſaccharine acid, by cryſtallizing the acid of lemons, and then examining this for the ſaccharine acid. It contained none. *Note*, That the citric or lemon acid is very eaſily cryſtallizable, by firſt combining it with lime, and ſeparating them by means of the ſulphuric acid. Even alcohol yields a little of this acid, when the action of the nitric acid on it is violent and long continued. Many animal ſubſtances yield it alſo, as Mr. Berthollet diſcovered: And ſome of them yield it in much greater quantity than ſugar does. Sugar yields one-third of its weight. Wool more than one-half.

There is, therefore, no good reaſon now for calling it the acid of ſugar, eſpecially ſince it has been found ready formed in ſome other vegetable ſubſtances, as in ſorrel. Since this acid has been well examined and characteriſed, the ſalt of ſorrel has been found to contain it, and to derive its acidity from it; the ſalt of ſorrel itſelf being

an alkali ſuperſaturated with this acid. *Vide Bergmann on Elective Attractions.*

We may here further remark, that all the vegetable acids are more or leſs ſimilar in their compoſition to the acid of ſugar, being compoſed of hydrogen, carbon, and oxygen, in different proportions. All theſe ſalts are convertible into one another *in a certain order*, by the action of the nitric acid on them. The acid of tartar is changed into the oxalic or ſaccharine, the oxalic into the acetous, and this into the carbonic. But this department of chemical analyſis is yet in its infancy, and it will probably be a long while before any perſpicuous knowledge of it will be acquired. We run a great riſk of being led into important miſtakes, by too confident application of imperfect and perhaps erroneous theory. We will correct with reluctance miſtakes which reſult from ingenious conceptions and laborious inveſtigation. The preſent ſubject in particular ſeems to encourage our reſearches by great appearances of ſucceſs; but the convertibility of acids, which at firſt exhibited ſuch uniform diſtinctions, ſhould make us extremely cautious in forming general concluſions. I have not room to enter into a diſcuſſion of ſo many particulars. Nicholſon gives the current opinions on the preſent ſubject with great candour and diſtinctneſs.

Thus we have conſidered the conſequences of mixing ſpirit of wine with alkalis and acids in different ways.

Of the compound ſalts, there are a few which can be diſſolved in this ſpirit; though the greater number cannot. The ſoluble are, the muriats of lime and magneſia, acetite of potaſh, the acetite and nitrat of ammonia. The reſt, in general, are not ſoluble, but, on the contrary, are precipitated by it from water. Hence it is that the fixed alkali which is diſſolved in vinous ſpirits, in the proceſs for rectification, is of the utmoſt purity. Mr. Woulfe employs this method for examining their purity.

Vitriolated tartar, after long digeſtion with vinous ſpirits, exhibits

ſome remarkable appearances. We obtain æther, ſulphurous acid, and volatile alkali.

None of the earthy ſubſtances have any remarkable action on vinous ſpirits.

Phoſphorus unites with it imperfectly, but without any phenomenon very intereſting to the chemiſt. Mr. Boyle may be conſulted on the ſubject.

Sulphur does not unite, even by long digeſtion. Count Lauraguais combined them perfectly, when in the form of vapour, iſſuing from two retorts. They form a fœtid liquor.

Charcoal ſpeedily clears ſpirits of wine from all diſtinctions of flavour, and makes all alike, and quite colourleſs.

VI.—OILS.

Under this diviſion I comprehend, along with what are commonly called Oils, the ſolid fats of animals, and reſins of vegetables, as being diſtinguiſhed only by a ſlight difference in fuſibility from the fluid inflammable ſubſtances of vegetables and animals, to which the term *oil* is in common language confined.

The bodies which belong to this diviſion are far inferior to alcohol in ſimplicity and inflammability. Yet, when their inflammation is properly excited, they give more heat and light than alcohol does. They are, therefore, ſtronger fuels, or may be conſidered as more inflammable ſubſtances than alcohol is. And yet they are not (many of them at leaſt) quite ſo eaſily ſet on fire, or brought into a ſtate of inflammation. Moſt of them require to be heated more, and their inflammation in ordinary circumſtances is not ſo complete. Their flame commonly throws out from the top of it a quantity of ſooty matter, called lamp black, the inflammability of which is not exhauſted. I call it ſooty matter; but it is a matter conſiderably different from common ſoot, which is an article of the materia me-

dica. This conſiſts partly of lamp black, or the half burnt oily matters of vegetables, and partly of many other ſubſtances, not inflammable, which are volatilized and expelled by the heat, along with the inflammable vapours. Soot generally contains an ammoniacal ſalt, formed of the volatile alkali, exiſting or generated by the heat, in the vegetable, and an empyreumatic acid of the acetous kind. Lamp black is a leſs complex ſubſtance, being the ſcorched or half burnt oily vapour, and is always produced when the flame is of ſuch a large ſize, or of ſuch a form, that the air has not a ſufficiently extenſive contact with it to act with full power on the whole of the vapour that compoſes it. But when the flame is of a ſmall ſize, or when a ſtream of air is made to riſe up through the middle of it, as in Argand's lamps, or when a ſmall ſtream of air is forced through it with the blow-pipe, the formation of ſoot is effectually prevented. I obſerve, however, that even a very ſmall and clear flame from oil, without the leaſt appearance of ſoot, carries up a minute portion of whitiſh earth, which, during a long continued proceſs with a lamp furnace, attaches itſelf to the bottom of the veſſel that is heated by the flame. This is certainly part of the aſhes, not volatilized, but merely blown out by the ſtream of vapour.

The component parts of oils are beſt diſcovered when we gradually convert them into vapours, and cauſe thoſe vapours to paſs immediately through a red hot tube, without mixing with air, into a proper apparatus for collecting gaſes. The reſult of this operation is the production of an immenſe quantity of *hydrogen gas*, mixed with ſome *carbonic acid gas*, and a ſmall quantity of *watery vapour*. And in the tube and diſtilling veſſel, when they are allowed to cool, we find a portion of charcoal, which, when burned in the open air, yields a ſmall quantity of aſhes, and a ſtill ſmaller of ſaline matter, commonly fixed alkali.

This analyſis, therefore, ſhews that the conſtituent principles of

oils are *hydrogen* and *carbon*, with a ſmall proportion of oxygen, and a ſtill ſmaller of earthy and of ſaline matter. The preſence of the oxygen is evident by the appearance of the carbonic acid, which is formed by the union of that principle with a part of the carbon, and alſo by our getting a ſmall quantity of watery vapour, which it forms by uniting with ſome of the hydrogen. The hydrogen gas obtained by this operation is neceſſarily of that kind which contains a ſmall quantity of carbon diſſolved in it, and which, on account of its being rendered denſer by this admixture than a pure hydrogen gas, is therefore named *heavy inflammable air*.

When the oils are ſubjected to the treatment which was named CHEMICAL ANALYSIS, by the elder chemiſts, in which they were merely diſtilled in retorts and receivers, and the vapours of them thus condenſed as faſt as they were formed, and without being ever made red hot, the products obtained are conſiderably different; for this reaſon, that the principles of the oil are not ſo completely ſeparated from one another. The greater part of the vapours are condenſed into an oil, or oily fluid, which has very different properties from thoſe of the original oil. And we get alſo ſome acid water, and ſome carbonic acid gas. And a ſmall portion of charcoal remains in the retort.

Repetitions of the ſame proceſs, with the ſame oil, diminiſh the quantity of the oil every time, rendering it more attenuated and volatile, and produce a little more water and a little more charcoal. And Mr. Lavoiſier diſcovered that more water was produced every time from the ſame quantity of oil, when the diſtilling veſſels were of a large ſize than when they were ſmall. He therefore concludes that all this water did not pre-exiſt in the oil, but was formed in the diſtilling veſſels from the hydrogen, which, uniting with the oxygen of the air contained in the veſſels, formed the water, or a great part of it. And the acid found in this water, and which is of a peculiar kind, is undoubtedly formed of a part of the oxygen, looſely com-

bined with a part of the hydrogen, and of the carbon, as it is in the vegetable acids. Dr. Crell of Helmſtadt made a very ſatisfactory ſet of experiments to inveſtigate its peculiar properties. They are publiſhed in the 70th volume of the Philoſophical Tranſactions. This acid is now named the *ſebacic acid*, and the compounds it forms with alkaline ſubſtances are named *ſebats*.

The conſequences are different when we apply heat to the oils in the open air, ſo as to inflame them in the moſt perfect manner. The whole of the hydrogen and the carbon unite with the oxygen of the atmoſphere, and form water, or vapour of water, and carbonic acid in an elaſtic ſtate.

I have long been of opinion, that a great quantity of water ariſes from burning oils. A plate of very cold glaſs or metal being held for a moment above a very ſmall and clear flame, will immediately be covered with dew; and a bell-glaſs held over the flame, and kept cold by ſnow, will ſoon have drops of water hanging at its brim. But Mr. Lavoiſier has collected this water more accurately and completely, by means of a well contrived apparatus, and he finds that it exceeds the weight of the oil. Something, therefore, ſupplied by the atmoſphere muſt contribute to form it.

The only queſtion is, whether this water has been exiſting previouſly in the air, or has been formed in the manner aſſigned by Lavoiſier? The laſt is more probable; becauſe we cannot ſee how the heat produced by inflammation can make the air depoſit water which it is ſuſpended when colder *.

If the inflammation be improperly managed, the change and deſtruction of the oil is not ſo complete. The ſoot which is produced from all oils, when we attempt to burn them with too large a flame, is formed principally from the carbon.

* It is perhaps owing to this actual formation of dampneſs, or water, that Dr. Franklin found that all electrical experiments are almoſt ſtopped, while a burning candle is connected with the inſulated part of the apparatus. We have the means of deciding this queſtion. EDITOR.

To treat of the oils more particularly, they muſt be diſtinguiſhed into two principal kinds, the AROMATIC and the UNCTUOUS; to which it is uſual to ſubjoin a third ſection, named EMPYREUMATIC.

The *aromatic* oils are all formed by nature, and chiefly in vegetables. In theſe they are ſecreted juices, lodged in particular parts or repoſitories in the ſtructure of the plant. All the aromatic oils make a ſtrong impreſſion on the organs of taſte and ſmell, exciting on the tongue the feeling of heat and acrimony. And they have not that ſmoothneſs and ſlipperineſs, when felt between the fingers, which is named *unctuoſity*. They are alſo all capable of riſing in vapour, in the heat of boiling water, or at leaſt along with the vapour of water. And they are very inflammable. The wicks of candles are often prepared for being quickly lighted up, by putting a ſmall quantity of ſome of theſe oils on the extremity of them.

The *unctuous* oils are alſo natural productions, and are found in vegetables and animals, in both of which they are alſo ſecreted juices, or are formed and lodged in particular parts or repoſitories.

When not corrupted, they have not any pungent taſte, or remarkable odour, but have unctuoſity in a great degree, and for that reaſon are much employed to diminiſh friction in machines of all kinds. The heat of boiling water is not ſufficient to convert them into vapour, and they are not ſo readily and quickly inflamed as the aromatic oils.

The *empyreumatic* oils reſemble the aromatic ſo much by many of their chemical qualities, that they are not diſtinguiſhable from them by any general difference, except the circumſtance of their origin. None of them are natural productions. They are all produced by art, and are either oils, changed from their natural ſtate by the action of violent heats, or are entirely produced by heat from vegetable or animal ſubſtances which do not contain a formed oil before the heat is applied to them. We may alſo add, as an article in the character of the empyreumatic oils, that the odour of them is in general offenſive.

Aromatic Oils.

Let us now take a nearer view of the firſt of theſe ſections, the aromatic oils.

We find almoſt the whole of them in vegetables. There are a few examples of ſimilar oils got from ſome animal ſubſtances, but they are very few. It is by examining vegetables that we find a great number and variety of theſe oils. All the vegetable ſubſtances which affect our organs with any remarkable odour, or hot pungent taſte, produce theſe effects by the action of an oil, or oily principle of the aromatic kind, which they contain.

And, as in a great number of ſuch vegetables, theſe oils are the moſt remarkable, and the moſt uſeful and active matter which they contain, they are for this reaſon named the ESSENTIAL OILS, or ESSENCES of ſuch vegetables.

The variety of them found in the different vegetables, or vegetable ſubſtances, is very great; but the greater number of them have not yet been found applicable to any uſeful purpoſe. And many others are contained in the vegetables in ſuch very ſmall quantity, that we cannot extract them except at a very great expence, far exceeding any value that can be ſet on them. Such, for example, is oil of roſes, which has the fragrancy of that favourite flower in the higheſt perfection. Roſes contain more of it in the warmer climates, and yet even in theſe, ſo little, that it is valued at an extravagant price. Some of this oil is collected in India, partly from roſe-water.

The odour of theſe oils, which is in moſt of them ſtrong and fragrant, is one of the moſt remarkable of their obvious qualities; and this odour is different and ſpecific in each particular oil. But they are diverſified by other properties beſides the variety of odours.

Some of them are extremely fluid, light, ſubtile, and volatile; others are more heavy and thick; and ſome are frozen in ordinary

heats of the air. Many taſte extremely hot, pungent, and acrid, when applied to the tongue. Some have a much milder taſte. And it is difficult to give any general rule with regard to theſe qualities. It is very generally ſaid, that the eſſential oils produced in colder latitudes are lighter than water, while thoſe of the hot are ſo heavy as to ſink in it. But this cannot be admitted as a general fact. The oil from parſley ſeeds ſinks in water. There are too many exceptions to it, and the ſame oil does not always appear of the ſame denſity. Oil of cinnamon will float or ſink, according as it has been drawn off by a gentler or a ſtronger heat. And I am inclined to believe that this inference, with reſpect to the weight of the aromatic oils of warmer latitudes, has been drawn chiefly from experiments made on the oils procured from the dry ſpices brought from the Eaſt and Weſt Indies, in which the oil is grown thicker and heavier by age and evaporation, and by combination with oxygen, than it was in the recent and green vegetable.

All authors have obſerved, with regard to theſe oils, that it is difficult to preſerve them long in perfection. The only way is to keep them in phials, with glaſs ſtoppers carefully ground to the phials, ſo as to ſhut them perfectly cloſe. And further, it is proper to ſet them in a cool place. If theſe precautions be neglected, they are ſure, after ſome time, to become leſs fragrant, leſs fluid, and generally to ſuffer a change of their colour. Theſe changes happen to them more quickly when they are expoſed to the air; and, in this caſe, a part of them commonly evaporates at the ſame time. Theſe particulars, therefore, ſhew that the depravation they ſuffer, if kept with too little care, proceeds, in part at leaſt, from exhalation of their more ſubtile and volatile part, upon the preſence of which their odour and tenuity chiefly depend. This is confirmed by the nature of the operation which has been found moſt proper for reſtoring again to a ſtate of perfection ſome part at leaſt of the oils which have ſuffered this depravation. This operation is to ſubject them to diſtillation, along with

ſome water, ſo that a part of the water and oil may diſtil over with gentle heat. Theſe oils, when recent and in perfection, are, in general, very volatile. Oil of ſaſſafras, for example, if dropped on a bit of paper, and held over a candle, at a great diſtance, will quickly diſappear, leaving no ſtain. They evaporate ſlowly if expoſed to air. And when the heat of boiling water is applied to them, they emit viſible ſteams, and evaporate copiouſly. This volatility they ſhew moſt remarkably when freſheſt and in greateſt perfection. When old and ill kept, we do not find them ſo volatile; at leaſt it is not ſo eaſy to evaporate them entirely. But if ſuch depraved oils be put into a retort with water, and part be diſtilled off, the part diſtilled is found to be much improved, and what remains in the retort to be grown worſe; that is, thicker, heavier, darker, and leſs odorous. If the diſtillation be not too long continued, the portion diſtilled is equal in goodneſs to the oil in its recent ſtate. By this operation, therefore, we recover, in a ſtate of perfection, one part of our depraved oil. And if it be repeated ſeveral times, we increaſe the tenuity and volatility of it, even beyond the natural or more ordinary ſtate; but, at the ſame time, we ſtill diminiſh its quantity ſo much the more.

Mere loſs of ſome of the more fragrant part is not, however, all the change which the aromatic oils ſuſtain by expoſition to the air. They actually combine with the oxygenous portion of atmoſpherical air. This was obſerved very early by Dr. Scheele and Dr. Prieſtley. The thickening of oils and reſins was one of the moſt effectual means of phlogiſticating the air in Prieſtley's numerous and important experiments, and indeed one of the moſt ſpecious arguments for his opinions. The oil exhaled its fragrant ingredient, which was thought replete with phlogiſton. The air was rendered unfit for the ſupport of flame. Scheele, however, drew a more warrantable concluſion. He ſaw that the air was diminiſhed in the ſame way as by the abſorption of hepar ſulphuris. Therefore, he inferred that the *fire-air* was abſorbed, and that the mephitic portion of atmoſpherical air alone re-

mained. He aſcribed the change on the oil to this combination. This has at length been evinced by clear experiments in ſome few caſes, in which the weight of the inſpiſſated oil was found greater than that of the freſh oil. When expoſed in vital air, the change is much more rapid and remarkable. The fact is no longer doubted.

When we try how theſe oils are affected by mixture with other bodies, we find, in the firſt place, that they can be combined in ſmall quantity with water, by churning and maceration. By this operation, the water acquires a good deal of the flavour, and ſtill more of the acrid pungency of the oil. But it does not contain any ſenſible portion of it, nor does the oil loſe any weight. The mixture can ſcarcely be called a chemical combination; for the water is ſoon covered with a ſhining film, which thickens by expoſure to the air (probably by abſorbing oxygen); and the water in a ſhort time loſes the greateſt part of the pungent taſte it had acquired. If a ſmall quantity of this water, while freſh made, and quite limpid, be agitated in a large veſſel filled with vital air, it becomes milky immediately, and much air is abſorbed. It would ſeem that it is this portion, ſo miſcible with water, that acts the moſt powerfully on oxygen, and combines with it.

Of the ſalts, the alkalis have a diſpoſition to unite with theſe oils. A compoſition of this kind has long been deſcribed by chemical authors under the title of *Starkey's ſoap*, formed of oil of turpentine, or of juniper, and the alkali of tartar. But they ſpeak of much difficulty attending the proceſs. This difficulty, however, proceeded from their taking the alkali of tartar in its ordinary ſtate. Dr. Crell found that cauſtic fixed alkali readily unites with the oil. This combination has not been much ſtudied, except for medical uſes, and it does not ſeem to be of much importance in this reſpect.

Combinations or mixtures of the volatile alkali alſo with theſe oils are formed for the purpoſes of medicine, on account of their having ſome medicinal powers ſimilar to thoſe of volatile alkali, viz. cordial, ſtimulating, and antiſpaſmodic. We have examples of ſuch

combinations in SPIRITUS VOLATILIS OLEOSUS, and SPIRITUS VOLATILIS FOETIDUS, and EAU DE LUCE.

When the nitric acid, in a concentrated ſtate, that is, having as little water as poſſible combined with it, is ſuddenly mixed with any inflammable body, its oxygen is ſo looſely combined, and retains ſo much of its latent heat, that it is immediately acted on, and its heat is extricated by combining with that body. If the ſubſtance is fluid, ſo as to allow an extenſive ſurface of action, and not ſo volatile as to be diſſipated in vapour at the firſt warming, the heat produced may increaſe to ignition. This is remarkably the caſe with the aromatic oils. Beſides this, they ſhew a remarkable diſpoſition to unite with oxygen. They are thickened by expoſition to the atmoſphere, as has been already obſerved, and this is attended by an abſorption of vital air. They have alſo a low temperature of inflammation.

For all theſe reaſons, when nitric acid is poured into an aromatic oil, ſuch as oil of cloves, or oil of turpentine, the mixture generates heat, boils up with great violence, and burſts out into flame. When this phenomenon was firſt obſerved, it was ſeen that a ſtrong acid was neceſſary, and as the proceſs for the *ſpiritus nitri fumans Glauberi* is particularly directed to every circumſtance that can enſure its concentration, this ſmoking acid was always employed: And it will always ſucceed, if the concentration be as perfect as we ſuppoſe. But you have ſeen that a very fuming ſpirit may be had that contains much water, merely by diſſipating ſome of the active ingredient by a little vinous ſpirits, ſugar, or ſuch like. Strong, pale, or nitric acid will much more ſurely produce the required effect. The manipulation preſcribed by Dr. Slare is alſo very proper, viz. to pour in about half of what we ultimately intend, and in four or five ſeconds after, to add the reſt at once. When the heat produced by the firſt is at the height, and has expended part of the ſtrength of the acid, we then add a parcel in its full force. Nor is the mixture of a little very ſtrong ſulphuric acid improper. This quickly generates a moſt inflammable

vapour (ſulphurous) which catches fire the more readily, as it meets with ſo much looſely combined oxygen in the nitrous acid. Nay, the ſulphuric acid alone, if clear and ſtrong, will inflame the heavy aromatic oils, ſuch as the oil of cloves,—and frequently too, in favourable circumſtances, even oil of turpentine. The mixture, when it does not kindle, acquires by long digeſtion qualities which greatly reſemble the bituminous oils and ſolid bitumens. If the acid has been diluted, the mixture has a ſoapy appearance, mixing pretty intimately with water.

Even the muriatic acid may be combined with oxygen (by a proceſs which will ſoon be explained to you) in ſo abundant and looſe a manner that it will fire the aromatic oils with great readineſs.

The neutral ſalts have no action on eſſential oils in mixture without ſuch heat as to burn them.

Nor have any of the earths except quicklime. By long trituration it renders them miſcible in ſome meaſure with water, and is thought to diſpoſe them to a more ready yielding their moſt odorous part by diſtillation.

Eſſential oils unite with ſulphur very readily, and compoſe balſams of ſulphur, drugs of a very diſagreeable ſmell and taſte, which have remarkable effects on the nervous ſyſtem. The vapours are highly inflammable. They alſo diſſolve phoſphorus, and the compound becomes luminous by coming into contact with the air, and takes fire in very low temperatures. The warmth of the hand is in many caſes ſufficient.

They are diſſolved by alcohol, but are ſeparable by water, and in ſome meaſure alſo by diſtillation. When we diſtil the alcohol, however, from an aromatic oil or vegetable, the more ſubtile and fragrant part of the oil generally riſes with the ſpirit, if a very gentle heat be employed. On this account, the odorous ſpirits diſtilled from them may be ſo prepared as to have a more ſubtile and delicate flavour than the odorous waters derived from the ſame oils, becauſe the heat of boiling water conſiderably exceeds that of boiling alcohol. Thus

are formed, from ſome aromatic oils or aromatic vegetables, the compound ſpirits and cordials of the apothecaries. Brandy is the ſpirit commonly uſed. Some of the fineſt perfumes are alſo prepared in this manner. *(See Beaumé.)*

Such is the general nature of the aromatic oils. There are a few, however, which differ ſo far from the reſt as to require ſome notice of their particular qualities. Theſe are diſtinguiſhed by the appellation of CAMPHORS. But there is only one ſpecies commonly known, and which is always ſuggeſted by that term; the others not being in uſe. The ſpecies I mean is that commonly uſed in medicine. It is got from a tree of the laurel kind, and has theſe qualities:

Firſt, it is, like the other aromatic oils, highly inflammable, burning with a moſt brilliant flame, but producing a good deal of ſoot; it leaves no aſhes whatever; it will burn on the ſurface of cold water; it is diſſolved in ſmall quantity by hot water, and imparts to it its taſte and odour; it is readily ſoluble in alcohol, and ſeparated by water. In all which reſpects it reſembles the reſt of the eſſential oils. It is particular by being always ſolid. When diſſolved in alcohol in great quantity, it cryſtallizes by evaporation of the alcohol, as alſo when it is ſlowly ſeparated by water, when the ſpiritous ſolution is ſet in a cold damp place. When heated, it does not melt, but evaporates, and ſublimes in beautiful cryſtals. And this it does more readily and completely than the other aromatic oils, never leaving, when pure, the ſmalleſt matter behind. It is therefore one of thoſe bodies which are more volatile than fuſible under the preſſure of the atmoſphere. But by confining it much, it may be melted*.

* In the proceſs for refining camphor, it is ſet in a ſand heat, in very low flat matraſſes, ſhaped like a flat turnip, and having a ſhort neck about an inch and a half in diameter. This is ſhut by a bit of paper looſely twiſted. In this ſituation I ſaw it boiling like water. The cake of ſublimate formed very faſt; and though the veſſel may be ſaid to be open, and more than a hundred were on the furnace, there was only a very moderate ſmell of camphor in the laboratory.

EDITOR.

The relation of camphor to acids is more remarkable. It is diſſolved by the ſulphuric and nitric acids, but without violence; and with the laſt it forms a fluid which appears like oil. Heat applied to this oil occaſions the acid and camphor to act on one another; and the acid is imperfectly decompounded, and gives out red vapours. By repetition of this proceſs, the camphor itſelf is changed into an acid which has peculiar properties, reſembling thoſe of the acid of ſorrel. Its properties have not been much examined, the preparation of it being very expenſive, and requiring eight diſtillations with freſh nitric acid. But it quickly loſes this appearance by the application or contact of pure water to it, which immediately attracts the acid from the camphor again.

This habit of camphor in relation to the acids, eſpecially the nitric, is its moſt diſtinguiſhing quality. This acid acts with ſuch violence on all inflammable ſubſtances, and particularly on the aromatic oils, and camphor being ſo eminently inflammable, we ſhould expect very different phenomena. The nitric acid ſuffers none, or almoſt none of the changes which reſult from a ſeparation of oxygen. There is, therefore, ſomething very peculiar in the conſtitution of camphor,—but it is of difficult inveſtigation. For, when a ſtrong heat is applied to it, it flies off unchanged, and cryſtallizes in the firſt cooler place it comes to. Many chemiſts think that camphor is the principle of aromatic oils and of reſins, but on what grounds I know not.

There is only one ſpecies of camphor uſed in medicine, or found in the ſhops; but there are ſeveral kinds, which may be obtained from different vegetables, and even from ſome aromatic oils already ſeparated from the plant, all of which have the properties I have now deſcribed, and differ from one another only by odour. Newman gives experiments and examination of a camphor which cryſtallized from the oil of common thyme; and he enumerates the roots of the cinnamon tree, zedoary, ſchœnanthus, cardamomus. oriental mint, abrotanum, milfoil, daiſy, juniper, roſemary, ſalvia camphorata, la-

vender, hyſſop, clary, maudlin, marjoram, &c. I am informed that it has been obtained lately from the leaves of the pimento, or Jamaica pepper tree. If ſo, we may ſoon expect it in great abundance, that being a very common tree, with exuberant foliage. Camphor is obtained from all theſe matrices much in the ſame way as from the laurus camphora, namely, by maceration in water, and then boiling the materials in an alembic, having the head occupied by looſe ſtraw. A good deal of the camphor ſublimes, attaching itſelf to the ſtraws, and the reſt goes over with the vapours into the receiver *.

As camphor is different from the reſt of the aromatic oils by theſe chemical properties, it is remarkably diſtinguiſhed from them alſo by its medicinal qualities, being much leſs heating and ſtimulating than the eſſential oils, though at the ſame time it has great powers as an antiſpaſmodic, an antiſeptic, and a diaphoretic. By its being free of the heating quality, it is ſafe and uſeful in a great number of diſeaſes in which the other aromatic oils are improper. But we muſt not give it in ſuch large doſes as are ſaid by M. Fourcroy to be given in England. Two ſcruples at once are not ſafe, except perhaps in mania. *(Vide Dr. Alexander's Experiments).* Applied externally, in ointments or other forms, it is very powerful in diſcuſſing or diſplacing rheumatic pains. But there may be caſes in which this uſe of it may be improper, as in external rheumatic pains of the thorax, unleſs other remedies are employed at the ſame time.

I may add, that when burning, its light ſeems to be the ſame, or to conſiſt of the ſame proportion of coloured rays, with that of the ſun. All delicate colours, which appear different in candle light, appear of the proper colour when illuminated by camphor.

And now I have ſaid enough of the aromatic oils. The manner

* From ſome trials, I am diſpoſed to think that both the wood and the leaves of the pimento, or Jamaica pepper, will yield a very good camphor: It is even deſerving of ſerious trial, becauſe camphor would be very extenſively uſed in ſeveral manufactures if cheaper. The pimento is ſo abundant in the Weſt Indies, that it would coſt nothing.

EDITOR.

of extracting them from the vegetables which contain them is ſo fully deſcribed in every book on chemiſtry and pharmacy, and it is ſo commonly known and frequently practiſed by the apothecaries, that I need not take up much of your time with it here.

The moſt common operation by which they are extracted is diſtillation of the vegetable with water. A quantity of the aromatic vegetable is put into a common ſtill, with as much water as floats it or covers it; and the diſtillation is begun immediately, or after a day or two. The hot water penetrates the vegetable matter, ſoftens it, and diſſolves more or leſs its aromatic parts, ſo as to diſengage the oil in ſome meaſure. And while the diſtillation goes on, the oil is changed into vapour, along with a part of the water; which vapour of the oil is carried over with the vapour of the water into the refrigeratory. Thus the oil is diſtilled over faſter than it could be with the ſame heat by itſelf, while, at the ſame time, the water prevents the vegetable, or the oil, from ever becoming hotter than 212° Fahrenheit, which it would certainly do, were it expoſed to heat by itſelf. And experience has ſhewn that theſe oils are the more fragrant in proportion as they are obtained with leſs heat.

The oily ſubſtances called BALSAMS and RESINS belong to the ſame diviſion with the aromatic oils, and reſemble them very much by their principal qualities. They are found in a number of vegetables, and, like the aromatic oils, are ſecreted juices, depoſited in particular ſpots, or particular veſſels of the plants. They are in general more or leſs odorous ſubſtances, and alſo produce the ſenſation of taſte, with more or leſs pungency and heat. They are all very inflammable, and burn with the ſame phenomena as aromatic oils, only they give more ſoot, and more fixed carbonaceous matter. Infuſed in water, moſt of them impart to it ſome taſte and odour. They are affected by acids as aromatic oils are. They diſſolve with eaſe in ſpirit of wine, and are ſeparable from it again by water. So far you may imagine I am deſcribing the aromatic oils.

The chief diſtinction is the degree of fluidity and volatility. Balſams in general are not ſo fluid or volatile as aromatic oils; and as there is great diverſity among them in the degree of theſe qualities, there are many that are commonly ſolid, and even conſiderably hard. The terms of balſam and reſin refer only to differences of this kind. The greateſt part of what are called balſams have a ſenſible degree of fluidity, and ſome are almoſt as fluid as ſome of the thicker oils. Reſins are ſolid and brittle in the ordinary temperature of the air; but if heat be applied to them, they melt into a viſcid oily fluid, which, ſo long as it is melted by a gentle heat, is not diſtinguiſhable from what is called a balſam. But the balſams themſelves vary greatly in conſiſtence by age. By the evaporation of their more volatile and odorous parts, they always become more ſolid, and even hard.

Theſe ſubſtances in general are more diſpoſed than aromatic oils to unite with alkaline ſalts. And it appears that ſoap-boilers have found it their intereſt, for ſome time paſt, to employ a proportion of common reſin in the compoſition of hard ſoap, by which they render it much more deterſive.

Beſides theſe differences of balſams and reſins from the aromatic oils, I juſt now ſaid that they are leſs volatile. This is true, however, with reſpect only to the greater part of their ſubſtance. When balſams and reſinous ſubſtances are expoſed to the heat of boiling water, or rather, are boiled with the water, they are always in part converted into vapour, and diſperſe their odour around. Of many, a very conſiderable part riſes along with the vapour of the water. This volatile part, when condenſed in diſtillation, is a perfect aromatic oil; and the part which remains in the diſtilling veſſel is a reſin, which becomes ſolid and brittle when cold, and is far leſs odorous and volatile than before. We have an example of all this in turpentine. If it be ſubmitted to diſtillation without addition of water, we firſt obtain from it a quantity of an aromatic oil, ſimilar to that which ariſes when it is diſtilled with water. But before it has all ariſen, the reſinous matter

becomes too hot; for it is capable of being heated to a much higher degree than that of boiling water. The heat, therefore, accumulates in it, and ſoon begins to decompound and deſtroy it; in conſequence of which it is changed into a ſpecies of empyreumatic oil, and a ſmall portion of water, and of vegetable acid. And a charcoal remains in the retort, in greater quantity than that which is produced from the aromatic oils when they are treated in a ſimilar manner.

It is worthy of remark, that when we diſtil turpentine with water, the produce of the diſtillation, together with the reſin in the retort, weigh conſiderably more than the original turpentine. The reſin and the oil are immiſcible with water. Water has, therefore, been ſo combined as now to form part (nearly one-ſixth) of the oil. Obſerve alſo, that the oil is vaſtly more odorous than the turpentine. This in ſome meaſure explains how effete aromatic oils are improved by diſtillation with water.

There is a conſiderable number of vegetables which contain balſams, or reſins, all diſtinct and diverſified from one another. And ſome have been found uſeful in medicine, and in the arts. Their powers in medicine are, in general, ſimilar to thoſe of the aromatic oils, but they are not ſo heating. In the arts, they are employed in varniſhes, paints, and perfumes, and other ſuch compoſitions: Alſo in natural hiſtory, for preſerving inſects.

Thoſe ordered by the colleges of London and Edinburgh to be kept in the ſhops are,

TEREBINTHINA *Chia*, ſive *Cypria*. Lond.

———— *Veneta*, (Ed.) From the larch of the Alps and Pyrenees. A kind from New England generally ſupplies its place in the ſhops.

———— *Argentoratenſis*, (Lond.) Straſburg turpentine, prepared in different parts of Germany, from the firs which are native and moſt common in England and Scotland.

BALSAMUM *Canadenſe*, (E.) Another fir in America, the Virgi-

nian, or Canada fir-tree, yields a turpentine much ſuperior, brought over under the name of *Balſamum Canadenſe*.

BALSAMUM *Commune*, (L.) The coarſeſt, &c. from the *pinus ſylveſtris*, common in different parts of Europe.

——— *Copaiba*, (L. and E.) From the Spaniſh Weſt Indies.

OPOBALSAMUM—*Balm of Gilead*. The beſt kind exudes from the plant in Arabia, but is never ſeen in Europe. The inferior is ſeparated from the leaves and branches by light boiling in water, but is alſo extremely ſcarce, ſo as to be hardly procurable.

BALSAMUM *Peruvianum*, (L. E.) From an odoriferous ſhrub in Peru, and the warmer parts of America, and extracted by coction. It does not unite with water, milk, unctuous oils, or wax. There is another balſam of Peru, of a white colour, and more fragrant, ſaid to be got by inciſion.

——— *Tolutanum*, (L. E.) From a tree of the pine kind in Tolu, Spaniſh Weſt Indies, and brought in little gourd ſhells.

BENZOINUM, (L. E.) The juice of a large tree, in both Indies, and bearing our winters: But the benzoin is brought from the Eaſt Indies only. It is uſed chiefly as a perfume. Water extracts very near as much of the flores by coction as is obtainable by heat.

GUMMI *Guaiacum*, (E. L.) Got by inciſion from a tree in the warmer parts of the Spaniſh Weſt Indies.

——— *Animé*. A reſin, got by inciſion from a large American tree. It diſſolves totally, though not eaſily, in ſpirit of wine, and has a tranſparent amber colour.

——— *Elemi*, (L.) A reſin, brought from the Spaniſh Weſt Indies, and ſometimes from the Eaſt Indies. It diſtils with water, gives a fragrant oil, and deſerves more notice.

——— *Hederæ*, From ivy.

GUMMI *Juniperi*, Exudes from the juniper, in warm climates.
SANGUIS *Draconis*, Brought from the Eaſt Indies.
SAGAPENUM, (L. E.) A concrete juice from Alexandria.
LABDANUM, (L.) Exudes upon the leaves of a ſmall ſhrub in Candia, and other iſlands of the Archipelago, and is bruſhed off with a ſort of rake, with leathern thongs for teeth. It ſticks to the thongs, and is afterwards ſcraped off. It is mixed with much ſand, and does not bear ſeparation by extraction, without diminution of its fragrancy.

I obſerved before, that the balſams and reſins are ſecreted juices in the plants which afford them. Many are collected by bleeding or extravaſation, at natural or artificial wounds, as turpentine. Others are an exudation or excretion from the ſurface of the leaves or other parts of the plant, as in the moſs roſe, and labdanum. Others are obtained by boiling gently with water. And ſome reſins are extracted from dried vegetable ſubſtances by the application of alcohol, and ſeparated from the alcohol afterwards by gentle diſtillation, or by the addition of water.

And now I have given a deſcription of the balſamic and reſinous ſubſtances, which is general, and applies to all of them except a few ſpecies. In all parts of nature, we find her productions ſo greatly diverſified, that it is impoſſible to give general characters and deſcriptions that will ſuit every particular. There are always ſome ſpecies, which muſt be conſidered as exceptions from the general nature of the reſt. In this light muſt we view three or four reſinous or balſamic ſubſtances, which I ſhall now mention. Theſe are copal, benzoin or benzoe, and ambergriſe.

1. COPAL is very tranſparent, and conſiderably hard, and is not diſſolved, but only ſoftened by alcohol. This diſtinguiſhes it from gum animé, which reſembles it perfectly in external appearance. But it can be diſſolved by ſome of the aromatic oils, and thus forms the moſt beautiful and durable varniſh employed in the arts. It was invented

in France, and long known by the name of *vernis Martin*. In England it is called copal varniſh, and is highly prized for its horny toughneſs. The art of preparing it is not commonly known.

When copal is treated with oil of turpentine in a cloſe veſſel, from which the vapours are not allowed to eſcape, they exert a great preſſure, which prevents the boiling, and the mixture acquires a higher temperature. A very conſiderable portion of copal is diſſolved; and with the addition of a little poppy-oil, it forms an excellent elaſtic varniſh, inferior to the vernis Martin only in a tint of brownneſs, ſcarcely perceptible.

Another good elaſtic varniſh is made of copal, by keeping it melted till an acid or ſour-ſmelling aromatic vapour has ceaſed, or become ſcarcely ſenſible. It muſt then be mixed with an equal quantity of lintſeed oil, which has been deprived of all colour by long expoſure to the ſun's light. The varniſhed ware muſt alſo be dried in the ſun.

2. BENZOIN is obtained from a tree in India, and is a balſamic ſubſtance of the more ſolid kind. It differs remarkably from moſt other balſams by the nature of its volatile part. It is not an aromatic oil, but a ſubſtance of a very peculiar kind.

Benzoin is commonly in the form of tears, like other reſinous exudations. It is very fragrant when hard rubbed, or when touched by a hot iron, or if ſprinkled on a hot plate; and is much uſed on the Continent for incenſing a room.

When merely heated, it ſwells up and becomes very fragrant; but when thrown on hot coals, it burns violently, and the odour is too piercing. If ſlowly heated in a low pipkin, on which a cone of paper is fitted, a vapour ariſes from it, which collects on the inſide of this cone in fine white ſpicular cryſtals. Theſe are equally fragrant, but provoke coughing. They are very acid, with ſome pungent bitterneſs. This is *flowers of benzoin*, or the *benzoic acid*.

The ſame cryſtalline acid matter may be obtained by boiling powdered benzoin in a great deal of lime-water, evaporating to a ſmall

quantity, and then detaching the lime by muriatic acid. The benzoic acid then cryſtallizes.

This is a ſingular ſubſtance, holding a ſort of middle rank between the aromatic oils and the ſalts. For it is highly fragrant, and inflammable, yet truly acid, uniting with all alkaline ſubſtances, and with the metals. It ſeems to maintain its character more firmly than any other vegetable acid. For it diſſolves in the vitriolic and the nitric acid quietly, and without inducing that change which they ſuffer from the loſs of a part of their oxygen. The nitric acid emits ſome faint ruddy fumes indeed, but without efferveſcence or commotion. A very ſmall quantity of water added makes the compound of nitric and benzoic acids float atop like an oil; but a little more ſeparates the latter in filaments, and unchanged in its properties.

Benzoin, like other reſins, diſſolves in alcohol, and is ſeparated by water.

3. AMBERGRISE differs from the other balſamic or reſinous ſubſtances chiefly by its origin. The greater part of what is brought to the market is found floating on the ſea, ſometimes in the northern parts of the Atlantic Ocean, but more frequently in the Indian Ocean, where it is ſometimes found adhering to the rocks on the coaſt. For a long time, very different opinions were formed of its origin. It was ſuppoſed by many to be a foſſil ſubſtance, which had been waſhed out of its original place by the waves. More lately, it was alleged to be the production of a tree in America, from which the ambergriſe iſſued as the balſams do from other plants, and that it was carried into the ſea by rivers. Had this been true, we ſhould have heard of this tree long before now, and got the ambergriſe from it. The lateſt opinion is, that it is formed in the body of an animal. There are many reaſons for believing that ambergriſe is really formed in that ſpecies of whale called the *phyſeter macrocephalus*, or *bottlenoſe*: 1*ſt*, Maſſes of it have been found in the bowels of the animal; and though it has been alleged that the animal, which is very voracious, had in this caſe found it in

the ſea, and had ſwallowed it, this is a mere ſuppoſition. 2*dly*, There are often found mixed with it, little bones of fiſh, and beaks, and feet of the *ſepia*, or *cuttlefiſh*, which is known to be eaten by that whale. 3*dly*, The ſubſtance of the ambergriſe is of a brown colour, and has a conſiſtence like that of bees wax, but contains numerous white grains which are calcareous. This does not occur in any vegetable production. 4*thly*, A ſmall maſs of ambergriſe, which I ſaw in Apothecaries Hall at London, was like a gall-ſtone. It had evidently a ſort of nucleus, ſurrounded with thick concentric layers. I am therefore inclined to ſuſpect that it is a morbid concretion, formed in ſome part of the alimentary canal of that animal, or in ſome cavities which communicate with it, in the ſame manner as the gall-ſtones are formed in other animals.

We may further add here, that ſubſtances remarkable by a ſtrong odour, are produced in a ſimilar manner in ſeveral animals. Such are muſk, civet, and caſtor. And there is in dogs a ſimilar matter, which has an inſupportable heavy ſmell; and in inſects of different kinds, as bugs, &c *.

That ambergriſe, though an animal production, muſt be conſidered as a balſamic or reſinous ſubſtance, appears from its properties. It has an aromatic odour, and it is volatile by heat, though not ſo volatile as aromatic oils. It is alſo ſoluble in alcohol. Its general appearances, however, more reſemble thoſe of the bitumens.

Musk, Civet, and Castor, cannot properly be called either oils, balſams, or reſinous ſubſtances. They are animal concreted juices, prepared by ſecretion; but they contain an aromatic oily principle, which gives them their odour, and which riſes in diſtillation with water. The

* There is a kind of whinſtone rock on the coaſts of Scotland, and alſo on the north ſhore of the Frith of Forth, which has many ſmall cavities, about the ſize of ſmall peaſe, or pin-heads, many of which are filled with a ſubſtance having the colour, conſiſtence, odour, and chemical qualities of ambergriſe. EDITOR.

quantity of it, however, is ſmall, or the nature of it ſuch that it cannot be collected by itſelf in form of an oil, but remains combined with the diſtilled water.

Before we diſmiſs the conſideration of balſams and reſins I muſt obſerve, that the term *gum* is often, and very improperly, applied to many of them in pharmacy; as to copal, gum-hederæ, guaiac, juniper, animé, elemi, benzoin. When the term gum is uſed with propriety, it is applied to ſubſtances totally different in quality from reſin. A gum is indeed a juice which exudes from plants, but it diſſolves in water, and not in ſpirit of wine. On the contrary, it is ſeparated from water by ſpirit of wine. And it has no more inflammability than any other vegetable ſubſtance. Gum-arabic is an example.

There is ſtill another ſet of products of vegetables to which the term gum is improperly applied. They are likewiſe inſpiſſated juices. Experiments ſhew them to be compoſed of a mixture of gum with reſinous, balſamic, or oily ſubſtances. Such mixtures are gum-ammoniacum, galbanum, ſagapenum, aſafœtida, opium, and ſeveral others. The proper name for theſe is Gum Resins. By applying alcohol, we diſſolve the reſinous or oily part, and leave the gum. Water, on the other hand, acts chiefly on the gum, and but very imperfectly on the reſinous or oily part. I ſay no more at preſent on this ſubject. We are to treat more of theſe things when expreſsly conſidering vegetable ſubſtances, as gum is a merely vegetable ſubſtance, which does not properly belong to any of the five claſſes of the objects of chemiſtry.

As among the reſins, ſo among theſe gum reſins, there are ſome diſtinguiſhed by their peculiar nature or uſeful qualities. Such, for example, is the ſubſtance called Lac, or Gum-lac. It is produced from the extravaſated juice of ſome trees in India, when they are punctured by a ſmall inſect in their tender new branches or ſhoots. The inſect is a *coccus*. The lac itſelf has all the chemical qualities of a reſin. It is of a deep red colour,—and makes the baſis of the finer kinds of ſealing wax, and of many varniſhes. The natural hiſtory

of this ſubſtance, and of the inſect which occaſions its production, is curious. *(See Phil. Tranſ.* 1781.)

The American concreted juice, called by the natives *caboutchouc*, is alſo a ſingular ſubſtance, which I think belongs to the gum reſins. It is the milk of a tree. It ſhews that it contains a gummy or mucilaginous matter by the effect of warm water upon it, which ſoftens it and makes it ſwell. And the reſinous or oily principle in it appears by the action of the ſulphuric æther, and by its inflammability. It is uſed for rubbing out pencil lines,—for injection bottles,—to form boots, portmanteaus, flexible perforated bougies, &c. But the manufacture of it is as yet extremely imperfect *. We get it in the form of little bottles. Theſe are formed by receiving the milk of the tree on clay moulds, by repeatedly ſmearing them over with the exudation, and drying each coat by a wood fire, the ſmoke of which gives it the dirty brown colour. When all is dry, the moulds are cruſhed and waſhed out.

This ſubſtance melts, but without forming a perfect fluid;—when cold again, its texture is quite changed, and its tenacity and elaſticity are gone. It burns with violence and much ſmoke, and leaves much coal.

No ſolvent has yet been found from which it can be ſeparated in an elaſtic and uniform ſtate. Nitrous æther diſſolves it, and may be evaporated from it, but leaves it filamentous like paper or waſhed leather, permeable to water. Vitriolic æther ſaturated with water is ſaid to ſoften it ſo that it can be eaſily joined in any way. The inſpiſſated juice of the fruit of the briony has a conſiderable reſemblance to *caboutchouc;* as alſo the juices of ſome plants which grow in the Eaſt Indies, ſuch as the *ficus Indica*, and a plant deſcribed in the *Aſiatic Reſearches* under the name of *urceola elaſtica.*

* An ingenious chemiſt of Glaſgow has diſcovered a method of expanding it to any ſize and thinneſs, as glaſs is blown. EDITOR.

Unctuous Oils.

Theſe are very commonly called EXPRESSED OILS, from the operation by which the greateſt number are extracted from the vegetable or animal ſubſtances which contain them.

Under this title I comprehend the ſolid fats of animals, which are but little different by their chemical qualities from the unctuous oils of vegetables: and there are vegetables which contain unctuous oils as ſolid as the animal fats.

Theſe oils are diſtinguiſhed from the aromatic by being mild, free of taſte and ſmell, and feeling unctuous or greaſy between the fingers; and beſides, they require a much ſtronger heat than that of boiling water to convert them into vapour; and they do not take fire ſo readily as the aromatic.

They reſemble one another upon the whole, more than the aromatic do. They are more nearly of the ſame gravity, being all lighter than water. And the greateſt number of thoſe which are commonly fluid are ſluggiſh and thick, compared with many of the aromatic.

As the unctuous oils, in their perfect ſtate, have no ſenſible odour, and are far leſs volatile than the aromatic, they do not ſoon ſuffer any remarkable loſs or evaporation by expoſure to the air, nor undergo the ſame change with the aromatic. But, in certain circumſtances, they are liable to another ſort of depravation, called *rancidity*. This appears when they have been too long kept, eſpecially in a warm place, or in warm weather. They acquire a thicker conſiſtency and offenſive ſmell, and a great degree of acrimony, or at leaſt a power to irritate the nerves of delicate ſtomachs with very great violence. The beginning of this ſort of corruption is generally attended with a diminution of the colour of the oil. Thus, the fine oil of olives, when freſh imported, and perfectly ſound, is of a ſtrong and bright yellow colour. When it begins to grow rancid, it becomes colourleſs, like

water; and this is the caſe with many others. The nature of this corruption has not yet been examined or explained. But I believe it depends upon a beginning reſolution and ſeparation of the principles of the oil from one another. I know that oils in a high ſtate of rancidity generate ſlowly inflammable vapours. Bellows of an iron finery were often burſt by the firing of an inflammable air produced within them from the oil with which the leather was anointed. This ranceſcence ſeems chiefly owing to an extractive mucilage which unctuous oils contain; for one way of preventing or greatly retarding it, is to churn the oil with a great deal of warm water, repeating this operation till it comes off perfectly clear from the oil. This change in the mucilage ſeems a fermentation, occaſioned by abſorption of oxygen; for Scheele obſerved, that oils becoming rancid abſorb and ſpoil air,—and it has been ſince found that theſe oils become much ſooner rancid in vital air. Oils and butter have been kept in water for fifty years perfectly ſound.

We find a great difference between theſe oils and the aromatic, in their diſpoſition to be affected by heat. I obſerved before that they are not near ſo inflammable; nor have they the leaſt degree of volatility in boiling water, nor even in degrees conſiderably above it. Moſt of them contain a little humidity and mucilaginous matter, which, when the heat riſes above that of boiling water, produces a little crackling and boiling; but this is ſoon over, and then the oil is capable of being heated to 400 or 500 degrees. But, as the heat increaſes, they begin to emit vapour and ſmoke, acrid and offenſive to the throat and eyes. The remainder becomes thicker, and darker coloured, and capable of receiving more heat; and the vapour and ſmoke become thicker, until at laſt they break out into flame. But before this, the oil is ſo hot, that tin and lead very eaſily melt in it, and it is nearly as hot as mercury boiling.

In many employments of the fat oils in the arts, it is neceſſary not only to clear them of the water they contain, but alſo to give them a

boiling heat, which acts on some of their principles, so as to produce changes which fit them for particular purposes. As this heat is near to that in which they catch fire, the operation is frequently performed out of doors. If, in this condition, a shower of rain falls, there is great danger of the oil's being dashed out of the vessel. If it falls from a height, it penetrates to some depth, where it is blown up into bubbles of elastic vapour, and it explodes, dashing the oil about on all sides. But beside this, it is discovered that water is decomposed by oils in this temperature, and a vast quantity of *inflammable air* is generated. One drop of water will produce above an English pint. This is the chief cause of the explosion, and increases the danger by its inflammability. Great heat is necessary for this action.

When we simply distil these oils in a retort without addition, the greatest part distils over in the form of an oil, quite changed from its natural state. It has acquired a brown or black colour, and a penetrating offensive smell, mixed however with some fragrance, and an acrid taste. It is now become one of the *empyreumatic* oils, which are soon to be described. The quantity of it is somewhat less than that of the oil was before this operation, but the deficiency is made up by a portion of water obtained at the same time, and into which a part of the oil is changed, as I formerly observed. In this watery fluid is found the sebacic acid of Crell.

By trying to mix the unctuous oils with other substances, we learn, in the first place, that they do not communicate any taste or other sensible quality to water, as the aromatic do; nor can they be dissolved in alcohol; but they can be combined readily and intimately with the alkalis, and form with them perfect SOAPS, which can be dissolved, either in water, or in a mixture of water and alcohol. To produce a good soap, we must take the alkali in its pure or caustic state. Common alkali will not do. The usefulness of soap, and its importance as a manufacture, are very well known. It derives its solubility in water, with its detergent and penetrating qualities, from the caustic alkali which

it contains. Nothing is ſo detergent and penetrating as the cauſtic alkali by itſelf. But the oil is neceſſary in the compoſition, in order to moderate the ſharpneſs and activity of the alkali, and to give a ſlipperineſs to the clothes to which the ſoap is applied. Were the alkali uſed alone, the clothes could neither be handled with ſafety in waſhing them, nor bear the hard rubbing and other mechanical violence neceſſary to extricate the matter which renders them foul.

The general proceſs for the preparation of ſoap is to boil the oils or animal fats with a ley made of pure or cauſtic fixed alkali. The boiling is continued till almoſt the whole of the water is diſſipated. The vegetable alkali produces a ſofter ſoap, and the foſſil a hard one. Soft ſoap can be changed into hard by boiling it with a ſolution of common ſalt. A double exchange takes place, and we have a muriat of potaſh and a hard ſoap. The proceſs is a little delicate.

If we decompound the ſoap, and ſeparate the oil from the alkali, we find that the oil will now diſſolve in alcohol by itſelf. It has undergone ſome change in this reſpect which we do not underſtand. We have an eaſy way of thus ſeparating the oil of ſoap for ſuch experiments, by adding an acid to it. The coheſion of the oil and alkali in ſoap is eaſily overcome by acids, which uniting with the alkali, immediately detach the oil.

From this effect of acids upon ſoap has been deduced the cauſe of what is called *hardneſs* in waters. Waters are called hard, when they decompoſe a little of the ſoap, and the oil comes to the top in a curdy form. We are told that ſuch waters as do not diſſolve ſoap are found to contain an acid, combined with ſome ſubſtance, which does not adhere to it ſo ſtrongly as to hinder it from acting upon the alkali of the ſoap. Neutral ſalts do not render water hard. Macquer was led into the miſtake that they did, by finding ſea water generally in this ſtate. But this is owing to Epſom ſalt contained in it. This ſalt, gypſum, alum, or metallic ſalts, always produce this effect. The addition of an alkali cures hardneſs in waters. This is too expenſive

when water is to be uſed in large quantity, as in bleaching, and other manufactures. In ſuch caſes, the choice of a good water is of immenſe conſequence. Many chemical trials and teſts are delivered by authors; but ſoap itſelf is the beſt of all.

The ſame hard waters are unfit for ſome operations in cookery, ſuch as boiling vegetables ſoft. A little alkali may be of uſe here, and would improve the colour of the vegetables.

The effects of the mixture of acids with unctuous oils, are not ſo violent in general as with the aromatic oils. When the experiment is made with the ſulphuric and nitric acids, a part of the acids is deoxygenated to a certain degree, but another part unites with the oil, and forms a compound which has ſome ſolubility in water, and is named an *acid ſoap*. Strong nitric acid, however, mixes with the fat oils with violence and the extrication of great heat. Some of them, which are called drying oils, and are found to have a ſuperior attraction for oxygen, are even ſet on fire, when the operation is judiciouſly managed, by pouring the ſecond quantity of acid on the part that appears dry and charred.

Of the earths, the pure calcareous earth, or lime in its active ſtate, ſhews a conſiderable diſpoſition to unite with theſe oils. We have an uſeful example of this in mixing any of them with lime-water, which will mix with olive oil very intimately by a little agitation in a phial, and the compound is found to be a moſt excellent extemporaneous remedy for ſcalds and burns.

Of the other inflammable ſubſtances, ſulphur is ſometimes combined with ſome of theſe oils, for the purpoſes of medicine, forming the Balsamum Sulphuris Crassum. It has a heavy hepatic ſmell. When the oil is very much ſaturated with ſulphur by means of a conſiderable heat, if the mixture be made to cool with extreme ſlowneſs, it depoſits a great part of the ſulphur in very beautiful tranſparent cryſtals of a dark ruddy brown colour. Sometimes the experiment

appears not to have ſucceeded; and if we give the veſſel a ſhake, it cryſtallizes in an inſtant, and ſo much heat is extricated that the mixture has ſometimes taken fire.

So far as we have proceeded, the account I have given is applicable to the whole of theſe oils. But, in order to give more full information upon this ſubject, it is neceſſary to point out a few ſpecies, diſtinguiſhed from the reſt by peculiar qualities. Theſe ſhew a little affinity with the aromatic, by containing a volatile principle, the preſence of which in them is neceſſary to their fluidity, and which preſerves them fluid in violent colds. It does not, however, give them an acrid and ſtimulating quality, for when they are quite freſh and uncorrupted, they are very mild; but it gives to ſome of them a perceptible odour. And, while it evaporates, in conſequence of their being expoſed to the air and to light, the oil becomes thick, and at laſt ſolid, for which reaſon, ſuch oils are employed as paints or varniſhes. This change is found to be accompanied with a copious abſorption of oxygen from the atmoſphere.

The oils that come under this deſcription, are thoſe of lint-ſeed, hemp-ſeed, poppy-ſeed, and walnut-oil. On account of their drying up, and thus leaving a varniſh on the ſurface of wood or other things to which they are applied, they are called Drying Oils. Other unctuous oils never dry, but remain greaſy, until they evaporate by decompoſition, or are abſorbed by duſt, or other impurities. The drying oils alſo unite with acids a little more violently, and more like the aromatic oils than the other unctuous oils do.

Spermaceti and bees wax alſo belong to the ſection of unctuous oils, but differ by ſome particulars from the general deſcription.

Spermaceti is an animal fat, gotten from a particular ſpecies of whale, and differs from other fats, chiefly by having much more ſolidity and dry conſiſtency in ordinary heats of the air. Hence it does not ſtain cloths, but rubs off; and in congealing, after being melted, it always diſplays a foliated texture. Dr. Crell made a very perfect ſoap

with it. It burns with a brighter flame than the greater part of animal fats.

Bees wax alſo differs from the unctuous oils, chiefly by having a greater degree of ſolidity in the ordinary heats of the air than moſt of them; by becoming ductile and plaſtic with a gentle heat before it melts; by giving a brighter flame; and by its origin. It is well known to be formed and uſed by the common honey bee in conſtructing its combs; and has generally been ſuppoſed to be formed by the inſect from the ſtaminal duſt of plants, which they are known to gather and carry to their hives. But Mr. John Hunter lately found reaſon to aſſign a different origin to it. He thinks that it is a ſebaceous excretion from their bodies, and comes out from under the ſcaly rings which cover their hinder parts; and that by the motion of thoſe rings on one another, it is formed into the very thin plates with which they make up their cells, and incruſt the inſide of their hive, and any extraneous body in it which might give them offence, as a ſnail, &c.

Among the effects which theſe oils ſhew in mixtures, we muſt not omit to mention ſome conſequences which attend mixing them with one another, as ſome of them in ſuch mixtures produce effects which demand the greateſt attention. There are ſome of them which ſoon after they are mixed begin to act chemically on one another. The mixed maſs becomes firſt warm, then hot, and at laſt takes fire; and, in ſome examples which happened in Ruſſia, has ſet fire to ſhips of war, or to magazines of naval ſtores.

Four pounds of ſuet, rather greaſy than firm, and half that quantity of lintſeed, hempſeed, or other drying oil, being mixed together, after a few hours become warm; and if this generated heat be prevented from eſcaping, by wrapping up the mixture in flannels, it increaſes to inflammation. The ſame effects follow when theſe oils are worked up into paints, with ochre and other colours; and when cloths, freſh ſmeared with them, are looſely rolled up in bundles, they grow hot, and ſcorch, and are thus conſumed to aſhes; and they frequently burſt into flame.

This propenſity to take fire ſeems owing to a ſtronger attraction of the ingredients for oxygen when in their compounded ſtate. Of this we have many inſtances, ſuch as ſulphur, phoſphorus, and mixtures of metals. The *black wad*, from Derbyſhire, was ſold for a black pigment, till it was found that cloths painted with it, ground with oil, could ſcarcely be laid up in the magazines without the riſk of taking fire ſpontaneouſly.

The origin and uſes of theſe oils deſerve our attention, as they are ſubjects of an extenſive commerce. Though the aromatic oils are more precious, theſe are incomparably more valuable and uſeful; but they are afforded by nature in far greater quantity, and therefore not ſo highly prized.

In many of the warm climates, the olive affords an excellent and very perfect unctuous oil in great quantity. In Africa, the negroes extract from the kernel of a palm an oil of this deſcription,—the *oleum palmæ*. An excellent oil, which keeps very well, may be got from the *arachis hypogaios Americanus* of Ray. The piſtil and germen of this plant point downwards, and penetrate the ground, under which the germen ripens to a ſort of nut, or huſky ſeed, called *ground peaſe*. It is much uſed for fattening fowls and ſwine. A buſhel of this ſeed coſts about eighteen pence, and will yield a gallon of oil of delicate taſte, and which keeps very well. (*Phil. Tranſ. vol.* 59.) * Through the whole extent of Europe, and in many other

* The oil expreſſed from the ſeeds of hemp, which has been carefully reared for this purpoſe, and cleared from all bad ſtalks, is, when freſh, almoſt equal to the fineſt butter in ſweetneſs. The offenſive odour of hemp oil is partly owing to the huſk, and partly to a natural change which this oil and ſome others undergo. The Ruſſians, who are very nice, chooſe for this purpoſe the ſeeds before they are grown hard and dry, and do not allow either the plant or the ſeed to lie in a heap. The oil when expreſſed is not perfectly fluid and tranſparent, but rather like honey beginning to grain. They put it into ſmall bladders, and keep it hanging in running water. I have eaten it three months old, and thought it preferable to their beſt butter.

EDITOR.

parts of the world, the ſubjects from which we get theſe oils are the animals which are ſlaughtered for our food, and the ſeeds of ſome plants, rape-ſeed, lint-ſeed, hemp-ſeed, beech-maſt, and walnuts,—and alſo milk, the butter of which contains an oil of this kind as its principal ingredient. But beſides, expenſive voyages are made to the polar regions, to kill whales of different kinds, for a plentiful ſupply of the oil they afford. The inhabitants of countries nearer the pole get their oil entirely from different marine animals.

The uſes to which theſe oils are applied are numerous and important.

1*mo*, They make up a part of the food of mankind in every part of the world in which they can be procured.

2*do*, They ſerve by their inflammation to give us light. And the Laplanders and Eſquimaux uſe their fiſh oil, not only as their beſt cordial and moſt luxurious food, but depend on it for both light and heat in their ſubterraneous dwellings during their long winter nights.

3*tio*, Soaps, which are among the moſt uſeful productions of the chemical arts, cannot be made without theſe oils.

4*to*, They are alſo highly uſeful and much employed in all machinery, to diminiſh friction.

5*to*, And laſtly, ſome of them are uſeful as paints or varniſhes.

Empyreumatic Oils.

As Newman, Lewis, and others, have treated of theſe oils ſeparately from the others, I have thought proper to follow the example. This term is applied to all oils which have been forced to riſe in vapour, and paſs over in common diſtillation, with a heat greater than that of boiling water, or which are produced by ſuch a heat from ſubſtances which were not oily before. When oily ſubſtances, ca-

pable of bearing a heat higher than that of boiling water, are expoſed to it, and made to aſſume the form of vapour, and diſtilled, they always undergo a change from their natural ſtate. Oils, which naturally are quite bland, inſipid, and deſtitute of odour, become acrid and ſtimulating, and ſtrongly fœtid, and diſagreeable.

Empyreumatic oils may be diſtinguiſhed into four kinds:

1. Thoſe produced from balſams or reſins.

2. Thoſe produced from unctuous oils.

3. Thoſe produced from vegetable ſubſtances that are not of an oily nature.

4. Thoſe produced by heat from animal ſubſtances not of an oily nature.

The firſt kind have, with the empyreumatic fœtor, an odour of the aromatic oil, which the balſam or reſin contained. The ſecond have the ſmell of the ſmoke of a candle or lamp when blown out. The third ſmell of wood burning. The fourth of burning feathers, horn, hair, bones, and other ſuch animal ſubſtances.

When theſe oils are firſt diſtilled, they are dark coloured, and even dirty, by reaſon of charry matter which comes over with the oil; but this oil being put into the retort, will riſe with a leſs heat, and comes over more volatile and attenuated, leaving a carbonaceous reſiduum. This operation, repeated ſeveral times, brings the oil to a greater degree of purity, and, which is important, of uniformity or ſameneſs,—in ſo much that it is highly probable that by repeated diſtillations all diſtinctions will be removed. Bees wax yields an oil which approaches the moſt rapidly to this ſtate,—and indeed, after two diſtillations, it can ſcarcely be diſtinguiſhed from an empyreumatical oil of olives that has been eight times diſtilled.

It may appear ſurpriſing to thoſe to whom it is new, that ſuch hard and dry ſubſtances as the hardeſt and drieſt wood, and the bones, horns, and other parts of animals, that have not the leaſt of

an oily nature, ſhould afford empyreumatic oils by diſtillation with a proper heat. The fact, however, is eaſily explained by the diſcoveries and new principles of the modern chemiſtry.

I lately remarked that all oils, in general, are principally compoſed of hydrogen and carbon, with a ſmall quantity of oxygen, and perhaps of azote, together with a very ſmall portion of earth.

Now theſe principles, which have thus been diſcovered to conſtitute the oils in general, are contained in all the animal and vegetable ſubſtances, as will be explained to you more fully hereafter, not excepting the dryeſt and hardeſt of theſe. When ſuch ſubſtances, therefore, are expoſed to the moderate action of deſtructive heat in cloſe veſſels, a part of the hydrogen, which is always a volatile ſubſtance, is volatilized, without being combined with that large quantity of caloric, which is neceſſary for converting it into inflammable air. It carries up with it a part of the carbon, and being condenſed by cold in the receiver, it muſt neceſſarily be condenſed into an oil, which is black, in conſequence of the carbon it contains, perhaps imperfectly combined with it, and has a penetrating diſagreeable ſmell, in conſequence of the imperfect union of the hydrogen with the carbon and other principles which it contains. If there be azote in the compoſition of the matter, which is the caſe with all the animal ſubſtances, and even ſome of the vegetable, this principle, combining with ſome of the hydrogen, forms ſome volatile alkali; and if there be much of the oxygen, which is the caſe with all the vegetable ſubſtances, it contributes to form a quantity of carbonic acid gas, and very often an acid now called *pyro-lignic (pyro-xylic)*, which is neareſt by its nature to the acetous acid.

The ſame view of the nature of oils in general will alſo enable you to underſtand why dark coloured acrid and fœtid empyreumatic oils are produced by ſubjecting to heat for diſtillation the mildeſt and moſt bland of the natural oils. The mildneſs and ſweetneſs and

unctuoſity of theſe depend on the proper union and coheſion and proportion of their principles, all of which conditions are altered by the action of heat.

The empyreumatic oils agree with the aromatic in ſeveral particulars. A ſmall quantity of them can be combined with water or diſſolved by it. They are diſſolvable by alcohol,—and they have not the lubricating quality of the unctuous oils.

All of them contain a very fluid and volatile oil, mixed with a groſſer one. And the tenuity, volatility, and inflammability of the more volatile part of them, is in ſome caſes very remarkable. Oil of wax is one of theſe.

One is valued in medicine, but not much uſed.—Oleum Animale, or Oleum Cornu Cervi Rectificatum. *(Pharm. Edin.)* Another, called *the oil of bricks*, becauſe it is diſtilled from a red hot brick which has been thrown into olive oil and impregnated with it, is uſed by the ſeal cutters and lapidaries, for moiſtening the diamond powder with which they work, that it may adhere to their tools.

The principal example we have of the application of oils of this diviſion to uſeful purpoſes is in the uſe of tar and pitch. Tar is the firſt production. It is procured from all the trees of the pine kind, by a rude kind of diſtillation. In Germany, Norway, and Sweden, where this timber is very abundant, it is piled up in billets in a ſort of oven, which is covered with another oven, at a very ſmall diſtance. The fuel is put into the interval between them. Thus the inner oven becomes a ſort of retort, and the oily vapours having no other outlet, run from a gutter made in the floor of the oven. This exudation contains much ſoot intimately mixed, which makes the tar quite black. Pitch is made of tar, by ſeparating the more volatile and fluid parts by evaporation or diſtillation. The tar is an empyreumatic oil extracted by heat, and contains a portion of the eſſential oil of turpentine, which is in all firs, and a quantity of the acid called now *pyro-lignic*. Hence tar-water, while it has that irritating acrimony

common to all the empyrumatic oils, is manifeſtly acid, and affects the vegetable purples.

VII.—BITUMENS.

The ſeventh ſection of the inflammable ſubſtances contains BITUMENS. Under this title I comprehend all the foſſil inflammables, except ſulphur, already deſcribed.

Some of theſe are fluid and ſome are ſolid. The moſt ſubtile of them is certainly that ſpecies of inflammable air which often occurs in coal-mines and other ſubterraneous places, and which I had an opportunity to mention formerly, as liable to take fire from the flame of candles, and to make dangerous exploſions. It muſt be conſidered as an inflammable ſubſtance of ſuch great volatility, that under no greater preſſure than that of the atmoſphere, the ordinary temperature of heat is much more than ſufficient to preſerve it conſtantly in the form of vapour. The hydrogen gas is ſurely its moſt abundant ingredient. I do not know that any perſon has made experiments with this kind of air, to inveſtigate the nature of it very particularly. But I have no doubt that it is heavy inflammable air, or that variety which contains carbon diſſolved in it *.

Next to this vapour, we may reckon the foſſil oil called NAPHTHA, and the varieties of it called PETROLEA. The naphtha is deſcribed as a fluid of a very light yellow colour, or ſometimes colourleſs; and which has a degree of fluidity and tenuity equal in appearance to that of alcohol or æther; but it is oily, and floats on water like æther. It is alſo very volatile, and highly inflammable, catching fire at the approach of flame rather more readily than alcohol. The flame of it,

* What eſcapes from the crevices of the Whitehaven coal-mines gives no indication of any carbon. The air in which it burns for a very long while does not affect lime-water.

EDITOR.

when not very ſmall, is attended with ſome ſmoke or ſoot, as that of all other oils. The odour of it is ſtrong and oppreſſive to moſt perſons. Such a fluid is ſaid to be gathered from the ſurface of the water of certain wells in Perſia, and in the duchy of Modena in Italy. But it is a rare production of nature.

The foſſil oils called petrolea are not ſo rare, but are inferior to naphtha in fluidity and volatility, though ſome are ſtill very fluid and volatile. The different varieties have different ſhades of a yellow or brown colour, and a heavy, oppreſſive, penetrating odour, and are highly inflammable. Such are found in ſeveral places in Italy, Sicily, Bavaria, France, iſſuing from the crevices of rocks, or floating on the waters of ſprings or wells, and readily take fire by the contact of flame, and burn on the ſurface of cold water.

The foſſil inflammable ſubſtances which are next inferior to theſe in fluidity, are thoſe to which the name of bitumen has been moſt particularly applied. Such are a number of ſpecies which have a conſiſtency reſembling that of tar or pitch, or that of the vegetable balſams. They are diſtinguiſhed, according to their different degrees of fluidity or conſiſtency, by the names of *piſſoleum*, *pix judaica*, and *piſſaſphaltum*. Some are little darker in their colour, or thicker in their conſiſtency than the coarſer petrolea, while the thickeſt, or moſt groſs, the piſſaſphaltum, is actually ſolid when cold, and requires heat to give it fluidity, in the ſame manner as pitch. When cutting a level to a coal mine on the bank of the Severn, near the iron bridge, a ſource of this kind was diſcovered in a ſtratum of free-ſtone. It yielded this tar in conſiderable abundance at firſt; but this gradually abated,—and after two years ſeemed to be exhauſted. It had accumulated in the pores of the ſand-ſtone through a length of time, and had now drained off. A ſimilar caſe occurred in Renfrewſhire a few years ago. St. Catharine's well at Liberton has yielded this ſubſtance for more than a century, and does not ſeem to abate. But the quantity is not great.

The very fluid bitumens are in general ſuch rare productions of

nature, eſpecially the more ſubtile and volatile kinds of them, that they have been but little examined by the chemiſts. They have much of the appearance and properties of the empyreumatic oils.

The ſolid bitumens are AMBER and COAL. The common appearance of amber is too well known to need deſcription. There are alſo varieties of it. The moſt valued pieces are of a light yellow colour, and either tranſparent, or agreeably clouded with white. But it is much more frequently found of a deeper yellow or brown, or even almoſt black and opaque. Amber is diſtinguiſhed by an aromatic odour, which it emits when rubbed. This and ſome other particulars give it a great reſemblance to ſome vegetable reſins. But it differs from all that are known in ſome of its properties.

If it be heated gradually, and the vapours condenſed in cloſe veſſels, it gives firſt a ſmall quantity of water. This is followed by a ſalt, part of which is diſſolved in the water, and part condenſed into a ſolid form. Along with this ſalt, and after it, paſſes over a large quantity of empyreumatic oil, and ſome inflammable gas. Little charcoal remains. This ſalt is an acid, ſtrongly tainted with the empyreumatic oil, more reſembling the vegetable acids than any other. The oil has an exact reſemblance to ſome petrolea, and if repeatedly diſtilled, becomes ſo like naphtha in every property, that they cannot be diſtinguiſhed.

The natural hiſtory of amber, as found on the coaſts of the Baltic, is given by Hoffmann and Newman; to which may now be added, that it has been found of late years abounding in Royal Pruſſia, near the ſhores of the Baltic, by digging pits of conſiderable depth, till they reach a ſtratum of foreſt trees, bedded in ſand, or at leaſt under a ſtratum of ſand. The trees are all charred, and perfectly black. The amber is found among them in neſts, and the working of theſe mines is found very profitable. The floating amber is, in all probability, torn up from the bottom, where the ſea has penetrated to this ſtratum. *(Crell's Annals of Chem.)* It is found in general in ſmall bits. Pieces

that are four, or five, or ſix inches in diameter, are exceedingly rare; and if they happen at the ſame time to have beauty, are very highly valued. It has, therefore, been a diſideratum among the chemiſts to unite ſmall bits of amber into larger maſſes; and ſome have been reputed to poſſeſs ſuch a ſecret. But it does not appear that the thing has ever been practiſed, or that it is poſſible.

PIT-COAL, the other ſolid bitumen, is of much greater value to the countries which poſſeſs it, in which it is well known to conſtitute thick, numerous, and extenſive ſtrata. And though inattentive obſervers conſider it all as the ſame, we find remarkable varieties of it in the different ſtrata which it forms. I ſhall here mention the moſt diſtinguiſhed varieties only. There are many others intermediate between theſe; but we need not attend to them all.

1. *Cannel coal*, or *candle coal;* or, as it is named by our colliers, *parrot coal.*

2. Common *Scotch coal*, in which our colliers diſtinguiſh ſome varieties; but we need not enumerate them.

3. *Fat*, or *caking*, or *blackſmith's coal*,—*ſmithy coal.*

4. *Kilkenny coal;* or, as our miners call it, *blind coal.*

Theſe different kinds of coal are diſtinguiſhed by their manner of burning, and by the products they afford, or phenomena they exhibit, when they are ſubjected to the operation called chemical analyſis.

The firſt kind, or candle coal, kindles eaſily, and gives in burning an extraordinary blaze of bright white flame.

The ſecond, which is the moſt common in this country, alſo gives in burning a good deal of white flame, though not ſo much as the firſt; and the cinder or charcoal that remains, when it ceaſes to flame, is a better fuel, or contains more of the carbonaceous principle than the cinder or charcoal of the candle coal.

The third kind, the fat, or blackſmith's coal, gives leſs flame in burning than either of the two former; but in beginning to burn, or before it begins, it is in ſome meaſure melted by the heat; at leaſt a

bituminous matter that is ſoftened and melted by the heat, oozes out of it, and occaſions the bits of it that are in contact to cohere together. So that, when a quantity of it, in ſmall fragments, or perhaps partly in duſt, is laid on a fire, and wetted with a little water, to make the fragments and duſt enter into cloſer contact, it very ſoon coheres together into one maſs, which being afterwards broken or divided a little, to let the air paſs through it, burns ſtrongly and a long while, giving a great deal of heat before it be totally conſumed. The cinder or charcoal of this kind of coal is very rich in the quantity of its carbonaceous principle.

This kind of coal is but rare in this country; but in ſome of the principal coal countries of England, Newcaſtle and Whitehaven, it is the moſt abundant. It is the moſt valuable of any, on account of its not ſuffering waſte by being broken down ſmall; for in the ſmalleſt fragments, it is equally good for houſehold purpoſes as the large pieces; whereas the greater part of our coal, when broken down to duſt and ſmall fragments, becomes quite unfit for houſehold purpoſes. By running like ſand into all the interſtices through which the air ſhould paſs, it extinguiſhes a fire inſtead of mending it. In this ſtate, therefore, it is not called coal, but *culm*, and is only employed for burning brick and lime, and for making ſalt from ſea-water. The Engliſh fat coal, though ever ſo ſmall, is never called culm, for this reaſon, that by its caking quality, it makes excellent houſehold fires, and gives a great quantity of heat before it be totally conſumed. It is alſo the moſt thrifty, as it does not burn much when the fire is left at reſt.

This kind of caking coal, when it is free from any admixture of ſulphur or pyrites, is alſo highly valued by the blackſmiths, and is even neceſſary in ſome meaſure to their operations. It enables them to make what they call a *hollow fire*. When they have occaſion to heat a maſs of iron, or a thick bar, they put it into their fire, and cover it with a large round heap of this ſort of coal, wetted on the outſide, and then by working their bellows for ſome time, and other ma-

nagement, the coals that were in immediate contact with the iron are conſumed, and a hollow is formed around it like an arch or little cavern, the ſides of which are all compoſed of coal caked together. While the wind of the bellows is driven into this cavity, and circulates in it, a violent heat is produced all around the maſs of the iron, and every part of its ſurface receives the neceſſary degree of it, which could not eaſily be obtained by uſing other coal that is unfit for forming the hollow fire. Such are the properties of the third kind of coal, the fat or caking coal, or ſmith's coal.

The fourth and laſt kind of coal I mentioned, the Kilkenny coal, or, as it is called by our colliers, the *blind coal*, differs greatly from the others by its manner of burning. It is more difficultly kindled, and when perfect of its kind, gives no flame whatever, but burns exactly like charcoal, and gives a great deal of heat before it is conſumed. As it neither gives flame nor ſmoke, it is burnt in malt-kilns for drying the malt, the air which comes from it in burning being quite free from fuliginous vapours. It appears probable, therefore, that the volatile parts of this kind of coal have been ſeparated or expelled from it by ſome operation of nature.

Such are the differences of theſe four kinds of coal in their manner of burning. They differ alſo, as I ſaid, by the products they afford when they are ſubjected to diſtillation performed without addition, in retorts and receivers.

I ſhall firſt deſcribe the effects of this operation when performed with the moſt common coal of this country, the common Scotch coal.

If the receiver be cloſely luted to the retort, and kept very cool, and provided with an air-pipe, we get, *firſt*, a ſmall quantity of water, little different from pure water.

Secondly, While the diſtillation advances, and the heat is increaſed, more water comes over, attended with a brown oil.

Thirdly, The heat ſtill increaſing, leſs of the water comes over, but

much more of the oil, and at laſt ſcarce any thing but black oil is ſeen to condenſe in the receiver.

The oil that comes at firſt is thin or very fluid, and of a brown colour. That which comes afterwards is thicker and darker coloured; and at laſt it condenſes quite black, and as thick as tar. It continues to come in the form of a thick ſmoke, to the end of the operation, that is, until the retort is heated to a degree of ignition, by which the remaining matter is changed into charcoal, and no more volatile matters can be expelled from it by an increaſe of heat.

Fourthly, During all the time, when the oil is diſtilling, eſpecially after the firſt of it has been condenſed, an immenſe quantity of elaſtic aëreal matter paſſes out through the air-pipe, and may be collected in inverted veſſels. A part of it is carbonic acid gas, which precipitates lime from lime-water. But the greater part is hydrogen gas, or inflammable air, not of the pureſt and lighteſt kind, but containing a quantity of the carbon, or carbonaceous principle, intimately combined with it. And therefore, when a mixture of it and oxygen gas or vital air are fired together, the conſequence is not the production of water alone, but of water and of a quantity of carbonic acid.

The whole of the oil is of the empyreumatic kind, not unlike to tar in colour and conſiſtence, only more fluid, and it has a very offenſive ſmell, ſimilar to that of the ſmoke of coal fires when they are beginning to burn. Like other empyreumatic oils it is partly compoſed of a very volatile and fluid part, and a groſſer one. They can be ſeparated by diſtillation with a gentle heat, by which we get a portion of the oil very fluid, and volatile, and tranſparent, and of a yellow colour, very much reſembling ſome of the petrolea. What remains in the diſtilling veſſel becomes more like tar or pitch in its conſiſtence and properties; and is now manufactured, in order to be employed as tar,—the more volatile oil being at the ſame time prepared for making a ſort of varniſh.

Along with theſe oils, I ſaid that a quantity of water is always ex-

tracted from the coal by the ſame operation. And this water contains ſome volatile alkali, which at firſt is intimately combined with ſome of the oil, but is ſeparated from it by rectification, &c. and afterwards can be employed in the manufacture of ſal ammoniac.

Theſe are the products which we obtain by diſtillation from the moſt common coal of this country. But there is ſome variation when we perform the ſame operation with the other kinds of coal I enumerated.

The candle coal yields a great deal more of empyreumatic oil and other volatile products than the other kinds.

The common Scotch coal is the next to it with reſpect to the quantity of empyreumatic oil, or volatile inflammable matter, which it affords.

The fat or caking coal affords ſtill leſs oil, but a very rich charcoal.

And the Kilkenny, or blind coal, affords none at all, and ſcarcely any volatile matter whatever. It may be conſidered as a natural charcoal.

Such are the principal varieties of bituminous inflammable ſubſtances found in the earth. And when we ſtudy their natural hiſtory, and ſome other particulars relating to them, we find great reaſon to be perſuaded that all have derived their origin from vegetable matter.

In pit-coal many appearances occur which lead us to ſuch a concluſion with regard to this ſort of bitumen. It is common to obſerve impreſſions of leaves and other parts of vegetables in the ſtrata, which lie above or below the coal; and very frequently in the coal itſelf we find a black matter, which has ſo much of the ſtructure of wood, and reſembles ſo exactly bits of wood which have been ſcorched or burnt to a ſort of charcoal, that there is no room to doubt of its origin. This matter frequently occurs in the coal which we burn here, and always forms a ſort of thin ſtrata intermixed with thoſe coals, and compoſing part of it, and occaſioning it to ſplit eaſily, in the direction parallel to the two ſurfaces of the ſtratum.

Sometimes little maſſes of the coal are entirely made up of this ſort of matter. I have been informed that ſome of the coals of England contain a remarkable quantity of it, and are diſtinguiſhed by the name of *clod-coal*, and valued as the beſt for melting iron from its ore. And the ſame matter appears in a bit of coal which was brought me from the coaſt of Greenland *.

From theſe and other facts and appearances, it has been concluded that pit-coal has been formed of vegetable matter, carried into the ſea by rivers, and which having ſunk to the bottom in conſequence of its being thoroughly ſoaked, has there undergone a degree of decompoſition, and has been ſtrongly compreſſed by other materials depoſited over it, and in ſome caſes has been penetrated with mineral vapours and ſubterranean heat, ſo as to give it the various qualities and appearances we ſee in coal.

The other facts, beſides the appearances already mentioned, which have ſuggeſted ſuch an opinion, are theſe:

1ſt, Great rivers, in different parts of the globe, are well known to carry annually vegetable matter into the ſea, eſpecially thoſe which have a long courſe through immenſe uncultivated tracks of the earth's ſurface that are overgrown with wood, as ſome of the great rivers of North and South America, Africa, India, and the Ruſſian territories. Great rivers neceſſarily have a great part of their courſe through level countries, through which they make many ſerpentine turns. And

* In 1759, coals were brought on board the Royal William, in Louiſburg harbour, which had been bought for the captain's firing. When his ſteward ſaw them, he refuſed to take them, ſaying that they were only charred wood. The vegetable ſtructure was very diſtinguiſhable in the greateſt part of them. One piece in particular had unqueſtionably been a large root of the common marſh iris. Its joints, and the commencement of the air veſſels at the big end, could not be miſtaken. Some pieces being firſt made red hot under ſand in a pipkin, ſo as to diſſipate a heavy ſtinking ſmoke, burnt afterwards with a ſmell perfectly reſembling that of wood charcoal. This coal had been brought in the boat from the mouth of the mine, in the face of a cliff, from which they had been let down by a pulley into the boat.

EDITOR.

they are conſtantly undermining their banks in ſome of thoſe turns, and occaſioning wood, leaves, moſs, and other vegetable matters, to fall into their ſtream. Some of this matter floats for a long time, until it be ſo thoroughly ſoaked as to ſink to the bottom. But while it floats, it is carried down to the ſea, and perhaps afterwards to a very great diſtance, by tides and currents. Sometimes it runs aground in the ſhallows that are at the mouths of ſuch rivers, and gradually forms iſlands in thoſe ſhallows, as at the mouth of the Miſſiſſipi; but the greater part is carried out to ſea. Great quantities of timber are found floating in the northern ſeas, on the coaſt of Iceland and Greenland, and the north coaſt of Ruſſia. All this, after floating ſome time, muſt ſink to the bottom. In Iceland there is a large bay which is always full of floating wood, and ſupplies the inhabitants with fuel.

2*dly*, The very circumſtance of coals being formed into ſtrata is ſtrong in favour of this opinion, as we have the greateſt reaſon to be ſatisfied that all ſtrata have been formed of matter carried into the ſea. But, beſides, we find theſe ſtrata of coal always intermixed with other ſtrata, which have been manifeſtly formed in the ſea, as ſandſtone, limeſtone, and clays of various kinds.

3*dly*, In ſome parts of the world, among ſtrata of the ſame kind with thoſe which commonly accompany coal, are found ſtrata manifeſtly compoſed of wood, even trees compreſſed and compacted together, ſo as to form ſtrata, bearing ſome reſemblance to thoſe of coal, but in which the wood retains ſo much of its original ſtructure and ſhape that it cannot be miſtaken. There is an example in Devonſhire, called *Boveycoal;* and a ſtratum of foſſil wood in the north of Ireland.

All theſe reaſons, therefore, leave little room to doubt of the origin of pit-coal in general, although, in many varieties of this bitumen, the firſt contexture of the materials has been ſo much aboliſhed by immenſe compreſſion, and the penetrating and diſſolving powers of water and heat, and other cauſes, that we hardly find any remains

of it. It is probable too that many ſtrata of coal have been formed of other vegetable matter, as moſs or peat,—carried into the ſea during a long courſe of time, by rivers which have their courſe through extenſive tracks of the earth's ſurface, abounding with bogs and moors.

When we ſtudy the varieties of the other ſolid bitumen,—amber, we can clearly trace its origin alſo from vegetable matter. It is not at all uncommon to find in amber, inſects of various kinds, either ſuch as creep on the trunks of trees, as ants, ſpiders, caterpillars, or flying inſects that frequently alight upon trees, or live upon them: Such are a variety of flies and moths. In the Britiſh Muſeum there is a lizard in amber; a reptile which is well known to creep on the trunks of trees, or to dwell about their roots. Further, theſe things are immerſed in the amber, and every way ſurrounded with it; and, from other appearances about them, it is plain that the amber muſt have been ſoft and viſcid, like the vegetable balſams, when they adhered to it, and when it involved them.

This, and the chemical qualities of amber, by which it reſembles greatly the vegetable, balſamic, and reſinous ſubſtances, gives ſufficient proof that it was once one of theſe. It is well known that many foreſt trees, in different parts of the world, at certain times of the year, ſhed from ruptured parts of their bark, large quantities of balſams or turpentines, a part of which muſt fall into rivers, or, if depoſited in the ſoil, muſt be waſhed out by them afterwards ſome time or other, while they gradually change their channel by undermining their banks. This matter muſt be rolled along by the river until it reaches the ſea, or is left behind, in ſome part of the bottom where the water has little motion, and by length of time, and the action of mineral vapours, aſſumes the qualities which we find in amber.

Such, therefore, appears to be the origin of the ſolid bitumens, coal and amber. That of the fluid may perhaps be thought more

difficult to trace. But I think we have clear lights for this part of our ſubject alſo. We muſt, in the firſt place, conſider that the fluid bitumens bear a ſurpriſing reſemblance to the empyreumatic oils which may be extracted or produced by fire from the ſolid. Some ſpecimens of the petroleum reſemble exactly the empyreumatic oil of amber; others reſemble the oils which may be extracted by fire from different kinds of pit-coal or foſſil-wood. And all the fluid bitumens reſemble theſe oils more or leſs. We muſt alſo reflect on the evident ſigns of ſubterranean fires which are frequent in different parts of the globe, particularly the hot ſprings, many of which pour forth amazing quantities of hot water, and thereby ſhew that the fires by which their heat is maintained have great power and permanency. This is further proved by the eruptions and ſteams of volcanoes, which are very numerous over the face of the globe, the fires of which muſt be at an immenſe depth below the ſurface, and muſt have very extenſive communications, as is plain from the extenſive effects of earthquakes, which manifeſtly depend on theſe ſubterranean fires. If to this we add what we obſerved in ſome kinds of pit-coal, which ſhew by their properties that the volatile parts have been expelled, it will be eaſy to gather from all this ſome highly probable conjectures concerning the origin of the fluid bitumens. We can hardly avoid being perſuaded that they have been produced by the long continued action of ſubterranean heat on the materials of the ſolid bitumens, the volatilizable parts of which are gradually ſeparated from the reſt by a ſort of natural diſtillation or chemical analyſis, and are driven upwards through the crevices or pores of the earth, until they come near to the ſurface, where they eſcape from the further action of the ſubterranean heat, and are within our reach. In confirmation of this ſuppoſition, it may further be remarked that ſome of the countries in which thoſe oils are found the moſt frequent, are well known to be undermined by ſubterranean fires, eſpecially Italy.

And not only the fluid bitumens, to which this name is commonly applied, but that more ſubtile ſubſtance, the inflammable air, or fire-damp, which occurs in mines, or breaks out at the ſurface of the earth in ſome places, can be imagined to have the ſame origin. When we expoſe the ſolid bitumens to the action of heat in cloſe veſſels, beſides the empyreumatic oils which we obtain, and which reſemble the fluid bitumens, we get alſo great quantities of inflammable air, or inflammable gas, which muſt neceſſarily be produced from ſolid bitumens or foſſil wood, on many occaſions by ſubterranean fires.

Thus, therefore, the whole of the ſubterranean inflammable matter that belongs to the title of bitumens may be imagined to derive its origin from vegetables. From whence the vegetables again derive theirs, will perhaps appear when we come to conſider the matter of vegetables, and its production, as a particular ſubject of chemical inquiry. *(See Note* 15. *at the end of the Volume.)*

CLASS IV.

METALLIC SUBSTANCES.

THE metallic ſubſtances are now to be conſidered as the Fourth Claſs of the objects of Chemiſtry.

They probably attracted the attention of mankind at firſt by their ſhining ſurface. But when their nature and properties became better known, they were valued as materials with which we can eaſily execute many purpoſes in arts which cannot be attained without them.

The qualities which render them uſeful and valuable are,

1*mo*, Their fuſibility and malleability, by which we are enabled to melt different maſſes of them into one, or eaſily to divide large ones into ſmall ones, and to mould or hammer, or otherwiſe work them into the forms which our purpoſes require.

2*do*, The ſtrong coheſion of their parts, in conſequence of which they are the proper materials for all parts of machinery, or other works in which great ſtrength or long duration is required.

3*tio*, The different degrees of hardneſs and elaſticity which ſome of them can be made to aſſume, render them highly uſeful to us on innumerable occaſions, for the fabrication of tools, ſprings, and many other implements neceſſary in the arts.

4*to*, The denſity of their ſubſtance, which is impenetrable to water, and moſt other kinds of matter, is one more of their uſeful qualities. And,

5*to*, and laſtly, Their bearing ſudden alterations of heat without being broken, is another.

Theſe ſeveral qualities render them uſeful for many different purpoſes; and further, by their luſtre and brightneſs, and the facility with which they are poliſhed and wrought into ornamental forms, they are fit ſubjects for many of the elegant arts.

The metallic ſubſtances are, for theſe and other reaſons, much more the objects of attention and ſtudy than the other claſſes of natural bodies.

And yet we have gained leſs advantage from the reſearches of many of the chemiſts on this ſubject than what might have been expected from the great labour which has been beſtowed on it. The reaſon is plain. The greateſt number of experiments formerly made upon metals were prompted by the viſionary projects and notions of the alchemiſts. Inſtead of directing their inveſtigations to the diſcovery of new productions that might be uſeful in life, their ſole aim was to convert cheaper metals into gold and ſilver. And it happened at the ſame time, that the greateſt number of thoſe who were employed in this purſuit, were perſons of ſo little education, and ſo ignorant, not only of other ſciences, but even of any rational principles of chemiſtry itſelf, or of the nature of the materials which they employed, that they were for the moſt part incapable of making experiments in a judicious manner, or of underſtanding them properly when they had made them. Their extraordinary labours muſt no doubt have led them to the knowledge of many curious facts; but every experiment which deſerved attention was concealed by them with the greateſt care, or if they mentioned, or pretended to deſcribe any diſcovery, they did it it ſuch myſterious and ambiguous language, as muſt render the ſtudy of it inſupportable to thoſe that ever read any thing elſe; beſides that they every where abound with abſolute falſehoods.

I ſhall not, therefore, attempt the diſagreeable and fruitleſs toil of inquiring into the meaning of their opinions and proceſſes, but con-

fine myſelf to ſuch an account of the metals as may be deduced from clear and ſimple experiments.

Upon this plan, I ſhall firſt mention the more general qualities of the metals, and afterwards deſcribe the nature of each in a more particular manner.

1*ſt*, The moſt obvious general quality of the metals is their great weight or denſity, in which they exceed all other known matter. The heavieſt ſtones are not more than four times as heavy as water, or ſcarcely ſo much. The lighteſt of the metals is ſeven times heavier.

2*dly*, They are remarkable alſo for a great degree of opacity, and a power of reflecting the light ſtrongly from their ſurface; in conſequence of which all mirrors are made of metallic ſubſtances, or are made to reflect light by their means. The thinneſt leaves or films of metal have this power to a ſurpriſing degree,—but we can in ſome caſes reduce them to films of ſuch exceeding thinneſs, that they tranſmit a very ſmall part of the light which falls upon them.

3*dly*, Metals are diſtinguiſhed from all other ſolid bodies by ſome qualities with regard to electricity, which give them the firſt rank among *conductors* of electricity, and which ſubject them on all occaſions to be more affected by lightning than any other ſort of matter which comes in its way. By conductors electricians mean bodies which are diſpoſed to receive readily and quickly the electrical fluid, and to tranſmit it in a moment through their whole ſubſtance and ſurface; ſo that when we communicate a charge of electricity to any one part of them, it is communicated to every other part of them at the ſame inſtant of time; or if we abſtract electrical matter from any one part of them, every part of them will be found to be equally affected by the abſtraction. Non-conductors are the oppoſite to this: They receive difficultly, and tranſmit very ſlowly. For this reaſon they are employed in electrical experiments for *inſulating* bodies,—and alſo for collecting the electrical fluid when we deſire to accumulate it or make it act on different bodies. The electrical fluid is collected in ge-

neral by rubbing a ſmooth poliſhed ſurface of theſe non-conducting bodies.

All other kinds of ſolid matter, provided they are made perfectly dry, have more or leſs of the *non-conducting* and *inſulating* power; but the metals have none of it. The electrical fluid, when accumulated in any other bodies, has always a diſpoſition to paſs from theſe to the metals, and to be diffuſed from one part of them to another, with ſuch aſtoniſhing velocity, that it can be conveyed by a wire to the greateſt diſtance without requiring any perceptible time for its paſſage. Mr. Cavendiſh found by experiments, that iron conducts the electrical fluid 400,000,000 times better than water; that is, a current of this fluid will paſs as readily through 400,000,000 inches of iron wire as through one inch of a cylinder of water equal in diameter to the wire.

4*thly*, Another quality of the metals in general is obſerved in their manner of aſſuming a fluid form by heat. They retain their opacity in their melted ſtate, and form a fluid which has a bright and reflecting ſurface, and which is repelled by moſt other kinds of matter, or which does not adhere to them, and ſpread itſelf on them, as water and many other fluids do. Small drops of melted metal, therefore form themſelves into little ſpheres, in conſequence of the ſtronger attraction of their particles for one another than for the ſurrounding matter. This happens not only when the ſmall drops of melted metals lie on the ſurface of various ſolid bodies, but alſo when they are immerſed in fluids, as water, oils, melted ſalts, and melted earths, none of which will mix with the metals, ſo long as theſe retain their metallic form.

Theſe ſeveral qualities of the metals,—their exceſſive weight,—the opacity and reflecting brightneſs of their ſurface,—their being ſuch perfect conductors of electricity,—and their mercurial manner of fuſion, as it is called, form the diſtinction between them and other

bodies, and are the only qualities which are found in them all without exception.

But we may alſo take notice here of malleability, laminability, and ductility, as among the general qualities of the metals; for, though theſe qualities are not found in all of them, the greater number have them, and metals are the only bodies in nature in which they are found in an equal degree. Theſe qualities are diſtinct from one another, and do not always go together. Some metals have all the three in a high degree, *e. g.* copper, ſilver, gold, and platina, when pure. Others have two only, as tin and lead, which are malleable and laminable, but not ductile. Others, on the contrary, as iron, are ductile, but not malleable and laminable. Others, as zinc, are laminable, but not at all ductile, and ſcarcely malleable.

The moſt malleable metals, however, are liable to become rigid and hard by hammering, in conſequence of the expulſion of latent heat; and they muſt be ſoftened again by annealing, before we can proceed to hammer them further. I had occaſion formerly to explain annealing, and how it is performed. Tin and lead are annealed in ſome degree by the heat of boiling water, and by a ſomewhat ſtronger heat are perfectly ſoftened. Iron, copper, ſilver, and gold, muſt be made red hot. Platina is with great difficulty annealed.

Such, therefore, are the more obvious general qualities of the metals.

To take, in the next place, a more chemical view of them, let us attend to the effects of heat on the metals in general.

1*ſt*, Each of the metals is well known to require a particular degree of heat for its fuſion; and ſome require very violent degrees. Dr. Boerhaave's opinion or ſuſpicion, concerning the heat of ſome metals in their melted ſtate, is perfectly groundleſs.

2*dly*, After a metal is melted, if we increaſe its heat to a much higher degree, moſt of them may thus be changed into vapour; and in cloſe veſſels, ſome of them can actually be diſtilled or ſublimed; though in general the free acceſs of air to ſuch metals, when violently heated, makes them evaporate much more readily than they will do in cloſe veſſels.

But, in order to underſtand fully the action of the air on the metallic ſubſtances, when they are ſtrongly heated, it is neceſſary to know that they greatly reſemble the inflammable bodies, by having a remarkable diſpoſition to attract oxygen, and to combine with it. And this combination, in ſome caſes, is attended with the ſame phenomena of heat and light as in the caſe of bodies commonly called inflammable. For example, filings of zinc, or of iron, when thrown into a clear coal fire, burn with a diſtinct flame. This inflammability appears from many other facts and experiments; among others, from the effects of nitre, when it is applied very hot to the metals: There is a deflagration, as it is called, in the ſame manner as when that ſalt is made to act on the inflammable ſubſtances, with this difference only, that, in the experiments with metals, it is neceſſary to apply a much ſtronger heat to bring on the action of the nitre and metal on one another. Filings of zinc, when thrown into melted nitre, burn with a flame ſo brilliant and dazzling, that the eye cannot bear it. If the nitre be red hot, filings of iron will exhibit the ſame appearance, but it is not near ſo brilliant. Filings of a mixture of lead and tin come next to theſe two in inflammability and brilliancy. The metals are thus ſuddenly changed into an earthy-like matter, which is mixed with the remainder of the nitre. I call it an earthy-like matter, this being its general appearance. It is ſtill, however, very different, according as the experiment is made with the different metals; but in none of them does it retain the appearance of any of the general qualities of metals which have been already deſcribed.

A further proof of the affinity of the metals to the inflammable ſubſtances is that they are liable to ſuffer a change by the joint action of heat and air, ſimilar to that which the inflammable ſubſtances undergo, a change analogous to inflammation. This change, in the caſe of the metals, was called CALCINATION. A higher degree of heat is neceſſary to bring on this change in moſt of the metallic ſubſtances than that which is ſufficient for the commencement and continuation of the

inflammation in the bodies uſually called combuſtible. And there is a certain latitude, or range of the ſcale of heat, which is beſt adapted to the calcination of the metals. In the lower degrees of this range, metals are calcined ſlowly and with difficulty. Near to the middle of it, the metals, in general, are the moſt quickly or perfectly calcined. In the higher degrees, the calcination does not go on ſo well. And when we increaſe heat to an intenſity much above the range I now ſpeak of, ſome of the metals expoſed to ſuch violent heats will retain their metallic form, though they may eaſily be calcined in inferior heats. The reaſon apparently is, that in very violent heats the air acquires too much elaſticity, and is too much rarefied, to act on them with ſufficient power; and the action of the air is fully as neceſſary to their calcination as the action of heat. If you would wiſh to know in what part of the general ſcale of heat this range fit for calcination is contained, I cannot be preciſe in pointing out its limits, as they are by no means diſtinct. I can only ſay that it appears to be comprehended within what are called the red heats, which, however, have many differences of intenſity. Below theſe red heats, and alſo in heats that are far above them, or what are called the white heats, calcination does not go on ſo well, at leaſt with moſt of the metals.

The matter into which the metals are changed by *calcination* is alſo an earthy-like matter, ſimilar to the matter into which they are changed by the action of nitre. The colour and other properties of it are different, according to the metal from which it is obtained, and partly too, according to the manner in which the calcination has been performed. This matter has been a long time called the Calx of the metal, and from it the operation by which it is obtained was called calcination. The term calx was choſen on account of a ſuppoſed analogy between the calcination of the metals and the burning of lime, though it is now well known that theſe two operations are of a totally different nature; and accordingly, the French chemiſts propoſe to ſet aſide theſe terms of calx and calcination, as very improper, and

to ſubſtitute others which I ſhall ſoon explain to you. In the mean time, we ſhall proceed to make a few more remarks on the calcination of metals in general.

In the firſt place, I wiſh you to underſtand, that metals, thus calcined, or changed into calces, are not always calcined to the utmoſt degree of which they are capable. By a certain moderate action of heat and air, they can be changed into calces, which may be further changed by a continued or more effectual action of the ſame powers. This gives occaſion to a great diverſity in the calces of ſome of the metals which are capable of theſe different degrees of calcination. A general account of which diverſity may be given in this propoſition, That the farther the calcination is puſhed, the more does the calx reſemble an earthy ſubſtance, or it is whiter, and the leſs diſpoſed to fuſion by itſelf; and on the contrary, the leſs they are calcined they have the more colour, or they are leſs white, and retain more of their fuſibility. Of this there are many examples, as in the calces of antimony, tin, and ſome others.

But the nature of the calx produced, and the phenomena and quickneſs of calcination, are very different in the different caſes, partly in proportion as the heat is more or leſs ſtrong, and more eſpecially, as the operation is performed with the different metals. You will eaſily perceive that there muſt be great variety in the calcination of the different metals, if you attend to theſe particulars:

1*ſt*, The different metals are more or leſs calcinable one than another. Some with great difficulty, and they are but imperfectly calcinable. Others are more calcinable, but ſtill are calcined ſlowly, and with ſome difficulty. Others, again, are much more diſpoſed for calcination, and, in proper circumſtances, are calcined eaſily and quickly. While there are others which can be calcined to a certain degree only, but after this, reſiſt the action of heat and air, without ſuffering much further change.

2*d*, If you alſo reflect on the great difference of the metallic ſub-

ſtances in their fuſibility and volatility; ſome being eaſily melted with a very moderate heat, while others require the moſt violent; and that ſome can alſo be eaſily converted into vapour, while others endure an intenſe heat a long time, without being volatilized by it;—you will perceive that the heats proper for their calcination muſt bear different relations to the heats neceſſary for their fuſion, or converſion into vapour. Some, which require ſtrong heats to melt them, are beſt calcined in degrees of heat inferior to thoſe neceſſary to their fuſion. Others, much more fuſible, muſt be melted and heated much above their melting point, before they can be calcined. And of the volatile metals, ſome do not calcine faſt, without applying to them ſo much heat as converts them into vapour.

Further, the calcination, in ſome caſes, goes on ſo ſlowly, or to ſuch a moderate degree only, that it is not attended with emiſſion of perceptible heat and light. But, in other caſes, there is a plain appearance of inflammation, the calcining metal being ſeen to glow like a burning coal; and in others, a bright flame is produced, like that of ſome volatile inflammable bodies.

What I have now ſaid will give you ſome general knowledge of the phenomena which attend the calcination of metals in different caſes and varieties of this operation. But you may form a more diſtinct notion of this variety by attending to ſome examples which I ſhall now relate:

1. Copper requires a ſtrong heat to melt it, and therefore calcines beſt in a heat inferior to its melting heat. It is not capable of being calcined faſt, or to a great degree; and no light or heat is obſerved to be produced by its calcination.

2. Tin is very fuſible, and therefore melts before it calcines; but when a proper heat is applied to it, it calcines faſt, and more perfectly than copper, and with appearances of combuſtion. The calx, when well calcined, is very refractory, or hard to melt.

3. Lead, like tin, is very fuſible, and therefore melts before it cal-

cines. When the calcination is performed with a ſtrong heat, the metal ſmokes all the while, or emits vapours; and it appears inflamed, or emits more heat and light than the ſurrounding matter,—and its calx, being a very fuſible one, flows around it in a melted ſtate.

4. Antimony is very volatile, and therefore emits vapours plentifully in a calcining heat, which vapours are at the ſame time calcined, and the calcining metal emits light and heat.

5. Zinc is ſimilar to the former, only more volatile, and in calcining, gives a dazzling light.

6. Lead and tin mixed. Mixing metals together increaſes their diſpoſition to calcine. It increaſes their fuſibility alſo, and therefore diminiſhes their coheſive attraction, which diminution of the coheſive attraction is probably a conſequence of the chemical attraction of the two metals for one another, as chemical and coheſive attractions are generally antagoniſts to each other. But by the diminution of coheſion the chemical attraction of the metals for oxygen will be increaſed *.

As the matter into which ſome of the inflammable ſubſtances are changed by inflammation can be reſtored again to its former ſtate, ſo the calces of metals can alſo be reſtored to their former ſtate, and made to reſume the metallic form. The operation by which this is effected is called REDUCTION, and is commonly performed by heating the metallic calx ſtrongly, in contact with charcoal, or mixed with it. Thus the charcoal, or a part of it, is conſumed, while the metallic matter recovers the metallic form. And to reduce a metallic calx in this manner, we can employ the charcoal of any inflammable ſubſtance from which a charcoal can be obtained, whether it be vegetable, animal, or foſſil. There are even examples of metallic calces

* I may juſt obſerve here, that Dr. Black, in his earlieſt lectures, aſcribed much of the increaſe of weight which is obſerved in the calcination of metals, to the abſorption of air, and its combination with the metallic ſubſtance. He obſerved that this increaſe is always ſmall when the operation is performed in cloſe veſſels, and aſſerted that there would be none in veſſels exhauſted of air. I have before me notes taken at his lectures in Glaſgow, in 1762, containing all theſe remarks. EDITOR.

being reduced, by inflammable ſubſtances, under other forms than that of charcoal; oils, and even alcohol, may be uſed. And nothing reduces the greater number of calcined metals better than hydrogen gas, when it is properly applied. This was firſt taught us by ſome of Dr. Prieſtley's experiments. He placed different metallic calces under glaſs receivers, or jars, filled with inflammable air, confined by water or mercury, and then applied to them the rays of the ſun, collected into a focus, by a burning-glaſs. The conſequence was, the quick reduction of the metallic calx, while a quantity of the inflammable air diſappeared.

Although any charcoal may be uſed in the reduction of a metallic calx, the moſt proper and convenient are charcoals of vegetable ſubſtances; and the charcoal of tartar is reckoned the beſt of all. It is, however, too coſtly for common occaſions, and is uſed only when the quantity of calx is ſmall, and we deſire to perform the operation neatly, and without loſs, as in aſſaying of ores, or in experiments with ſmall quantities of metals;—and the operation is performed in a crucible. The reaſon why charcoal of tartar is the beſt is, that it contains an alkali in ſuch quantity as renders it fuſible: It therefore applies itſelf more cloſely to the metallic matter, and alſo diſſolves or melts any earthy matter which may happen to be preſent; in conſequence of which fuſion the particles of reduced metal more eaſily ſink to the bottom of the mixture, and unite there to form one maſs, called in this caſe a REGULUS. The charcoal of the tartar prepared for this purpoſe is called BLACK FLUX.

But in the large way of working, when tons of metallic calces are to be reduced, they are ſimply heated in contact with the fuel, and intermixed with it. In the great iron furnace, the ore, broken into ſmall pieces, and mixed with ſubſtances which promote the fuſion, is thrown into the furnace, and baſkets of charcoal, or coaks, in due proportion, are thrown in along with it. A part of the bottom of the furnace (which is alſo the narroweſt) is filled with fuel only. This being kindled, the blaſt of the great bellows is directed on it, and ſoon

raiſes the whole to a moſt intenſe heat. This melts the ore immediately above it; and the reduced metal drops down through the fuel, and collects at the very bottom;—The reſt ſinks down, to fill up the void left by the conſumed fuel and metal. Thus it comes in the way of the bellows; and here it is raiſed to the ſame intenſity of heat, and melts, and is reduced, in its turn. More ore and fuel are ſupplied above; and the operation goes on, till the melted metal at the bottom, increaſing in quantity, riſes almoſt to the aperture for the blaſt. It is now let out, by piercing a hole in another ſide of the furnace, cloſe to the bottom.

There is an opinion among the chemiſts, founded, as they ſay, upon experience, that the leſs calcined calces are moſt eaſily reduced, and that the calces of ſome metals, if expoſed to the action of heat and air for a long time, can hardly be reduced at all, or not without a conſiderable loſs. Hence the notion of a *mercurial principle*, &c. in metals, which they imagined to be partly expelled and loſt by violent calcination. I ſuſpect, however, there is another more ſimple reaſon for the loſs or diminution of the metal, which is, that all the metallic ſubſtances, whether calcined or not, have more or leſs of volatility, and are liable to ſuffer a loſs by evaporation, when they are long expoſed to the action of heat and air.

After thus deſcribing the calcination of the metals in general, and the reduction of them again to the metallic ſtate, I have been accuſtomed to mention the opinions which have been formed of the nature of theſe operations, and the arguments and proofs on which theſe opinions are founded.

The moſt diſtinct and plauſible opinion, which prevailed among the chemiſts for a conſiderable period, was that of Dr. Stahl, ſimilar to that which he entertained concerning the nature of the inflammable ſubſtances and of inflammation, viz. that the metals are compounded ſubſtances, conſiſting of that matter which was called the calx, and of the phlogiſton; and that they had their metallic qualities from the principle of

inflammability; and that during calcination, this principle was ſeparated from them; and therefore the baſis or calx of the metal appeared in its ſeparated ſtate, deprived of the metallic qualities; but that in the operation of reduction, the calx recovered again from the charcoal, or other inflammable matter, the phlogiſton which it had loſt, and by this recovery, was reſtored again to the metallic ſtate.

This appeared ſo far a plain intelligible account of the matter; but there was one material fact, which was a very great difficulty in the way of this theory. The fact I mean is, that the quantity of calx is greater than that of the metal,—one hundred pounds of lead, for example, produces 110, or 112 pounds of calx.

Different attempts were made to get over this perplexing difficulty,—ſome of them very extraordinary, and almoſt incomprehenſible, *e.g.* that the principle of inflammability was not only deſtitute of weight, but that it had the power of diminiſhing the weight of bodies to which it was added, &c *.

All theſe difficulties proceeded from their not having yet ſtudied the part which air performs during calcination. This was not ſufficiently done until of late, when the nature and powers of the different airs, or elaſtic fluids, became ſo much the ſubject of inquiry.

Among the experiments which this inquiry has occaſioned, it was ſoon diſcovered by Dr. Prieſtley, Scheele, and Beccaria, but eſpecially by M. Lavoiſier, and other French chemiſts, that when a metal is calcined, it always abſorbs and fixes a part of the air which contributes to its calcination and is neceſſary to it; and that the increaſe of weight in the calx is always equal to the quantity of the air abſorbed.

* Nor could any valid objection have been made to this explanation, however unlike our more familiar notions, had not Sir Iſaac Newton made experiments on pendulums of all different kinds of matter, metals, and the calces of metals, and found that all vibrated alike, if of equal length. Chemiſts acquieſced, however, in this explanation by Stahl, becauſe few, if any of them, were mathematical philoſophers, and as few of the mathematicians were experienced chemiſts. EDITOR.

Dr. Mayhow of Oxford obſerved this in the caſes of antimony and lead, and ſuſpected that it was ſo in all,—1674.

It has further appeared from ſuch experiments, that it is always oxygen gas which the metals attract in this manner. They are calcined moſt eaſily and quickly in pure oxygen gas, and cannot be calcined in any other, except when it contains a mixture of the oxygen, as atmoſpheric air does. When calcined in a limited quantity of atmoſpherical air, therefore, they extract the vital part from it, after which the reſt of the air has no more power to calcine them *.

It has alſo been proved in the cleareſt manner that oxygen gas can be extracted from the calces of metals; from ſome by heat alone,—the calx at the ſame time recovering its metallic form. This happens to mercury, ſilver, gold, platinum. From others, the oxygen gas may be extracted by an elective attraction, as happens in lead, the calx of which, viz. minium, affords oxygen gas by the action of ſulphuric acid aſſiſted with a moderate heat. On the other hand, in the reduction of metallic calces by the action of charcoal, a great quantity of elaſtic aëreal matter is extricated from the materials, which is carbonic acid, that is, a compound of oxygen and charcoal. All theſe particulars are now completely proved by many experiments; and upon theſe M. Lavoiſier and his friends founded their new ſyſtem concerning calcination and reduction, totally oppoſite to that of the older chemiſts. The new opinion is, that the metal is not a compound, but a ſimple body,—that the calx is compounded of the metal and oxygen extracted from the vital air,—that the heat and light are no proof of a principle of inflammability. They are extricated chiefly from the oxygen gas, which is ſuppoſed to have an extraordinary capacity for heat, and which, as being an elaſtic fluid, contains a great deal beſides in a latent ſtate.

In reduction again, the new doctrine is that the oxygen is ſeparated

* A ſimilar doctrine was maintained by Mr. Bayen, a French apothecary. *Journ. de Phyſ.* III. 120,—IV. 487,—VII. 390.

from the metal, and nothing elſe happens or is neceſſary to the recovery of the metallic ſtate; and therefore, in the reduction of mercury, ſilver, gold, and platinum, which have but a moderate attraction for oxygen, heat alone is ſufficient to ſeparate it. Other metals cannot be reduced by heat alone, on account of their having a ſtrong attraction for the oxygen, and retaining it too ſtrongly to admit of its being forced off by heat: But ſuch are commonly reduced by the action of charcoal, aided by heat; and then the carbon attracts the oxygen from the metal, and forms carbonic acid with it. The production of carbonic acid gas in this manner has been aſcertained by numerous and inconteſtable experiments. And when inflammable air is employed, the baſis of this air, the hydrogen, acts like the charcoal, by its ſtrong attraction for the oxygen that is in the calx. They unite together, and form water. This alſo has been aſcertained by many experiments.

A change of ſome names has been propoſed in conſequence of this theory, viz. *calx* and *calcination* are to be ſet aſide, and calcined metals or calces are to be named Oxyds. *Des oxydes*, in French, *oxydum,-da*, in Latin. But this term of oxyd is applied by the French chemiſts to every compound, whether metallic or not, that contains oxygen in leſs quantity than that which gives acidity.

On the whole, this ſyſtem is much more directly and plainly ſupported by facts and experiments than the ancient ſyſtem of the chemiſts.

The only fact which the French theory has not yet explained is, the effect of light in reducing the oxyds of metals. There are ſeveral examples of it, in conſequence of which it is ſuppoſed, by the defenders of the old doctrine, that the light unites itſelf to the metallic matter, and thereby reſtores it to the metallic form. But it muſt be acknowledged that when metallic oxyds are reduced by light, oxygen gas is always detached; and the French chemiſts ſay, that the light affects the reduction, not by attaching itſelf to the metallic oxyd, but

by ſome power which it has to occaſion the ſeparation of the oxygen, perhaps by joining with it, and thus forming with it oxygen gas.

One fact more, which has been diſcovered by the experiments lately made on the metallic oxyds, muſt not be omitted, viz. That many of them, when once formed, are capable of attracting carbonic acid, and of uniting with it, and even of being diſſolved by it in water, like the alkaline earths.

I now proceed to conſider the properties of metals reſpecting their mixture with other bodies.

The firſt claſs of the objects of chemiſtry,—the ſalts, and of theſe the acids, are found to have the greateſt activity with regard to metallic ſubſtances, and to produce the greateſt variety of effects.

To give a general idea of thoſe effects, I may begin by ſaying that there is a chemical attraction between metals and acids; that metals are capable of uniting with acids, much in the ſame manner as alkalis and the alkaline earths are,—that they are diſpoſed to form with them ſaline compounds, many of which readily cryſtallize; and in moſt, the natural activity or corroſiveneſs of the acid are very ſenſibly abated by its adheſion to the metal, though, in general, not near ſo much as in the ſalts compoſed of alkalis or earths.

The chemical combinations of metals with acids are commonly named *ſolutions* or *diſſolutions* of the metals, on account of their being commonly produced by putting the metal mechanically divided, or with an increaſed ſurface, into the liquid acid, which acts on it as a ſolvent. The action of the acid is promoted by gentle heat, and alſo by annealing or ſoftening the metal before it is put into the acid. This laſt practice is uſeful, probably, by diminiſhing in the metal that ſpecies of coheſive attraction called *hardneſs*, which is an antagoniſt to the power by which the diſſolution is performed. At any rate, the fact is certain. If we take a few of the ſmall caſt iron tacks, (made

of the white metal) which have not been annealed, and as many of the ſame tacks long annealed, and put each parcel in equal quantities of acid, the laſt will be found much more diminiſhed in weight than the other in the ſame time. Moreover, the unannealed nails ſeem to reſiſt moſt at the ſurface, and when half diſſolved, preſerve their form completely. In this particular metal, indeed, a ſpongy nail remains coherent to the laſt.

In performing theſe diſſolutions of the metals, we find alſo that in many caſes there is a mutual ſaturation, as with the acids and alkaline ſubſtances; a certain quantity of acid being capable of diſſolving, and converting into a ſaline compound, a certain quantity only of the metal; and the metal on the other hand, neutraliſing or mitigating a certain quantity only of the acid. This does not happen however in all the compounds of metals with acids. In many of them there is no fixed point of ſaturation, the ſame quantity of metal being capable of combining with different proportions of acid, and forming compounds which differ in appearance and other qualities, according to the proportion of acid which they contain. Even in this caſe, however, it is not ſo properly ſaid that there is no fixed point of ſaturation. The fact would be better expreſſed by ſaying, that the ſaturation is not confined to one proportion. For, in theſe caſes, we find that when a certain proportion is attained, the addition of more acid, for example, diſſolves the ſalt, without changing its properties, till we reach another proportion, when a manifeſt change of chemical and other properties enſues. Sometimes we ſhall have a third proportion, in which a kind of ſaturation obtains. This reſembles the combination of water and ſalt, in the ſtates of cryſtal and ſolution, and in the combinations of heat, inducing ſolidity, fluidity, or vapour. When the proportion of acid is large, the acid is leſs mitigated, and the compound is more ſoluble in water, and in ſome caſes deliqueſcent. When the quantity of acid is very ſmall, it is much mitigated, and the compound has little or no ſolubility, the metal being only divided by the acid into a

powder, and not diſſolved. In this caſe, that is, when the acid divides the metal into a powder, but does not diſſolve it or render it ſoluble in water, it is ſaid to *corrode* it, and the metal is ſaid to be *corroded.*

It muſt be underſtood further, that every metal is not equally diſpoſed to unite with each of the acids. Some of them can be combined with all the acids, or any of them; but others with a certain number of them only. And there are ſome which are not acted upon in the leaſt, except by one or two, or by certain mixtures of the acids with one another.

Thoſe metals which are capable of uniting with a number of the acids generally have the ſtrongeſt attraction for the muriatic, and next to the muriatic, for the ſulphuric. The acid of ſugar, or the oxalic, and the tartarous acid, and the phoſphoric, are alſo ſtrongly attracted by the metals in general. The nitric acid, although it diſſolves a great number of the metals readily and eaſily, is not ſo ſtrongly attracted and retained by them. It is more eaſily ſeparated from them by heat or otherwiſe. The muriatic, when combined with them, is ſo ſtrongly retained, that it is not ſeparable by heat, but renders the metallic matter volatile along with itſelf.

Among ſeveral metals which can be diſſolved by the ſame acid, great differences are found in their attractions for it, and ſome of them can be employed to precipitate others in a certain order. Zinc or iron, for example, can be employed to precipitate ſilver, or quickſilver, or copper, or lead, from the nitric acid. Lead precipitates copper, quickſilver, or ſilver. Copper precipitates theſe two laſt; and quickſilver precipitates ſilver. Zinc is therefore ſuppoſed to have the ſtrongeſt attraction for the acid; next to zinc, iron,—next lead, copper, mercury, and ſilver.

There is a remarkable circumſtance which diſtinguiſhes the ſolution of metals in the acids from the ſolutions of alkaline and other ſubſtances. While metals are diſſolving in acids there is, in many caſes, a violent effervеſcence,—an effervеſcence ſometimes as ſtrong as that

which attends the action of acids on common alkalis or calcareous earths. It is, however, quite different in its nature from the effervescence of alkalis or alkaline earths. It is not produced by the separation of fixed air or carbonic acid. The metals in their metallic state do not contain any. These effervescences are explained in a very satisfactory manner by a great number of the modern experiments, which shew that either a part of the acid or a part of the water is decomposed by the dissolving metal, which attracts to itself a part of their oxygen, and is thereby changed into an oxyd, (formerly called *a calx*) which oxyd, as a peculiar substance, is dissolved by the remaining acid, or is united to it. When the oxygen is taken up by the metal from a part of the water, hydrogen gas is produced in the efferveſcence, as you saw lately when iron was dissolved in diluted sulphuric acid. When the oxygen is taken up from a part of the acid, the acid is partly decomposed, and a different elastic fluid, or other matter is produced, peculiar to that acid. All this will be more fully explained as the cases occur. *(See Note* 16. *at the end of the Volume.)*

We find reason to be satisfied that this theory is well founded, when we examine the state to which the metals are reduced by being dissolved. A metal, while dissolving, is always calcined, or oxydated, more or less; in many cases, it is true, to a very small degree only, but in every case, some degree of this change does happen to it; for, if we precipitate the metal by the action of a pure alkali, we always get it in form of a calx; and we get it in nearly the same state if we expel the acid from it by the action of heat alone. And when, on the other hand, we change the metal into an oxyd by the action of heat and air, before we apply the acid to it, there never is an effervescence, the metallic matter generally dissolves quietly, in some cases more easily than the metal itself, when put into the same acid. But this happens only when the metal is calcined in the slightest degree possible, If much calcined, it dissolves more slowly and difficultly,

and requires a greater quantity of acid to its diſſolution than the metal itſelf would have required.

We may further remark here, that the different acids act on the metals with different degrees of quickneſs and violence. The action of the nitric is generally the moſt quick and violent, and moſt effectual in oxydating the metals. Next to this the ſulphuric. The muriatic acid generally acts in a more ſlow and languid manner on the metals in their metallic ſtate. This appears plainly to proceed from its having leſs of the oxygen to impart to the metal; for if the metal be firſt ſlightly oxydated, no acid whatever unites with it ſo readily and ſtrongly as the muriatic acid. We have a proof of this, when we add muriatic acid to a metal already oxydated by another acid, as the nitric, or even the ſulphuric acid. There are alſo particular ſtates or conditions of the muriatic acid, in which it acts more readily and powerfully on the metals than it does in its ordinary watery ſtate. We apply it, for example, in ſome caſes, in the form of dry and hot vapour, as in cementation, deſcribed in my general account of chemical operations. And there are other proceſſes ſoon to be deſcribed, by which we add oxygen to the muriatic acid. By this its power to penetrate and diſſolve the metals is greatly increaſed.

The compounds, or the ſolutions of metals with acids, are of different colours, when made with different metals, or with the ſame metals in different ſtates of oxydation.

Fourcroy (*Annales de Chymie, tom.* x. *on Mercurial Precipitates*) mentions an opinion of the French chemiſts, that the colour of the ſolution or compound is ſimilar to that of the oxyd contained in it, and that when, from ſuch ſolutions or compounds, a precipitate is produced of a different colour, this proceeds from a change the oxyd has undergone in its degree of oxydation, while it was precipitated, or immediately after. Yet he ſays, (page 309, *et alibi*) that Turbeth mineral, or ſulphat of mercury, with exceſs of oxyd or calx, is ſoluble in 2000 waters, and forms a colourleſs ſolution. Cauſtic alkalis pre-

cipitate from this ſolution a grey oxyd. This colour indicates ſome degree of deoxygenation. Fourcroy imputes this change to the cauſtic alkalis: But this is no explanation.

The compounds of metals with acids may be decompounded in general without difficulty. The acid and oxyd are united together in the greater number of caſes, by an attraction that is not very ſtrong, which is plain from its being overcome by many other attractions; by alkalis, the alkaline earths, and even by ſome of the inflammable ſubſtances, which are diſpoſed to unite with acids. If freſh calcined litharge (which is an oxyd of lead) be ground to fine powder, and be put into a ſolution of lime in muriatic acid, we find the lime precipitated in a cauſtic ſtate, and the liquid now contains a compound of lead and the acid. Or if ſea ſalt be digeſted with litharge, we procure a cauſtic mineral alkali. *(Scheele on Fire*, 174.*)* This explains the corroſion of the lead pipes which convey water. It very commonly holds both of theſe muriats in ſolution.

Heat alone is ſufficient, in many caſes, to ſeparate acids from metals. All this proves that the attraction between them is not ſtrong, in the greater number of caſes. It is probably in conſequence of this moderate attraction, that in ſome of the compounds of metals with acids, the acid is very little mitigated, the compound being nearly as corroſive, when applied to animal ſubſtances, as the pure acids themſelves. In this way we have obtained ſome of the moſt uſeful potential cauſtics and eſcharotics employed by the ſurgeons.

This being a very general property of the metallic ſalts, and being a property purely chemical, becauſe it is equally effective on the dead and on the living ſubject, has attracted the attention of the chemiſts, and they have attempted to diſcover ſome general principle on which it depends. Mr. Berthollet, unqueſtionably one of the moſt eminent, publiſhed a diſſertation on this ſubject in the *Journal de Medicine* in 1779. He aſcribes it to the action of the acids on the phlogiſton contained in animal and vegetable ſubſtances, and ſupports this by a very

judicious ſeries of experiments. The doctrine of phlogiſton being exploded, this explanation, as far as it was valid before, is eaſily accommodated to the new doctrines, and we muſt aſcribe the corroſive power of the metallic ſalts to the action of the oxygen which they contain. It is very true, that the action of oxygen produces very remarkable effects on animal and vegetable ſubſtances. But I do not think that they have a great analogy with the action of the highly corroſive metalline ſalts, ſuch as that formed of mercury with the ſulphuric, nitric, and muriatic acids, or that formed by ſilver and the nitric acid. Some of thoſe ſalts are moſt highly corroſive when they contain the ſmalleſt quantity of oxygen, a quantity ſo ſmall that they are ſcarcely ſaline, and very ſtrongly united. Others are more corroſive when they are truly ſaline, and contain not only oxygen, but alſo the diſtinguiſhing ingredient of the acid; and others are ſo far from being corroſive in either ſtate, that they promote the healing of wounds and ſores, ſeeming friendly to the functions of organiſed ſubſtances. Perhaps the corroſiveneſs is ſufficiently accounted for, when we aſcribe it to the acid itſelf. Nor is it incongruous with the general courſe of chemical facts to ſay, that in ſome of theſe compounds, new properties are induced, differing from thoſe of either ingredient.

The other order of ſimple ſalts, the alkalis, have not ſo much diſſolving power with regard to metals as the acids. They are more commonly employed to precipitate metals from acids, which they do by their great ſuperiority of attraction.

The ſeparation of a metal from ſolution in an acid, preſents ſuch a variety of phenomena, that I can ſcarcely bring them under general rules, and ſhall therefore notice them as they occur in treating the ſeveral metals. I may obſerve, however, in this place, that in moſt caſes, a ſmaller quantity of alkali is ſufficient for ſeparating a metal from a given quantity of acid, than ſuffices for ſaturating this quantity of pure acid. The precipitate is in the form of an oxyd, and in theſe caſes, has decompoſed part of the acid. It is only the remainder

that employs the alkali to ſeparate it from the metalline oxyd. How this is effected, even in thoſe caſes where water is decompoſed, and inflammable air is produced, muſt be conſidered as a difficulty ſtill remaining in the new doctrines of the French chemiſts.

The alkalis themſelves may alſo, in ſome caſes, be made to act as ſolvents, and will diſſolve moſt metallic ſubſtances very perfectly. They act moſt powerfully in their cauſtic ſtate, eſpecially if applied with a melting heat. In the ſtate of watery ſolutions, they act but weakly in general, though there are ſome of the metals which they diſſolve very perfectly even in this way. And if the metal be previouſly oxydated, eſpecially by acids, there are few of them that will not yield to the action of alkalis.

Thus it happens, in many caſes, that when we precipitate a metal from the ſolution in an acid, by a cauſtic alkali, if we put in too much alkali, we rediſſolve the metallic oxyd. The volatile alkali does this in moſt caſes. A certain preparation of alkali, which will be deſcribed in due time, enſures the alkaline ſolution.

In a dry melting heat the alkalis are powerful ſolvents of the metalline calces, and form with them a variety of coloured glaſſes.

Among the compound ſalts, borax is found uſeful in the melting of gold and ſilver, and in ſoldering theſe and other metals. Its uſefulneſs is remarkable, eſpecially when filings or ſmall pieces are to be united by fuſion. It helps to make them melt more readily, and to join all together the more completely, and with the leaſt loſs. The borax promotes the union of the melted particles or globules of the metals, by making their ſurfaces clean and bright, and preſerving them in that ſtate. The neceſſity of this is plain in mercury, which the ſmalleſt foulneſs hinders from uniting. Its globules are then rather diſpoſed to ſeparate into ſmaller globules when we attempt to bring them together. And the borax effects this, by covering and defending the metal from air, and thereby preventing the formation of any calcined cruſt or pellicle, and likewiſe by diſſolving any matter of this kind which

is already formed; borax having much power to diſſolve and melt the earthy ſubſtances and metallic oxyds. By ſpreading itſelf alſo over the ſurface of the crucible, it gives a ſmooth glazing, which allows the metal to be poured out.

The other neutral ſalts are not much diſpoſed to act on metallic ſubſtances, except when aſſiſted by a ſtrong heat, but, with its aſſiſtance, thoſe which contain the acids that have the greateſt power over the metals are diſpoſed to act upon them, and diſſolve or corrode them, more or leſs, the acids being looſened by the heat. Glauber's ſalt, vitriolated tartar, common ſalt, and digeſtive ſalt, produce this effect. The effects of nitre and ammoniacal ſalts are more remarkable. Many of the metals, when they are thrown into melted nitre, are inflamed or burnt, as has been already ſeen, and the metal is reduced to the ſtate of an oxyd. This oxydation concurs with the effects which you formerly ſaw in the mixtures of nitrous acid with alcohol, to ſhew how eaſily the nitric acid is decompoſed. No part of it is to be found in the crucible, if enough of metal have been employed. We find only a cauſtic fixed alkali, ſometimes, indeed, tainted by the metallic oxyd which it has diſſolved. Hence we muſt conclude that the metal is oxydated by attracting the oxygen of the nitric acid, and thereby allowing the nitrous air or the azote to eſcape. This eſcape muſt be conſidered as the cauſe of the deflagration.

The effect of common ſal ammoniac upon the metal is eaſily underſtood. The attraction of the acid for the volatile alkali is ſcarcely greater than for ſome of the metals or their oxyds. Therefore, when one of them, in fine particles, is mixed intimately with ſal ammoniac, and diſtilled, we obtain the volatile alkali in a cauſtic form; a proof, by the way, that metals do not yield fixed air in their effervescence with acids. In this decompoſition of the ammoniacal ſalt, the effect is brought about by the heat, which volatilizes the alkali. The vitriolic ammoniac exhibits the ſame appearances.

The oxyds of ſome metals, when put into a watery ſolution of ſal

ammoniac, act with great variety of appearances, which will be explained afterwards.

With reſpect to the ſecond claſs of the objects of chemiſtry, the earths, the relations of theſe to metals in general has been, in ſome meaſure, pointed out already, and amounts to a very few propoſitions only. I have already obſerved, that ſome of the alkaline earths have a ſtronger attraction for acids than moſt metals. I alſo had occaſion to notice that melted earths and melted metals cannot be mixed, at leaſt ſo long as the metals retain their metallic form. But when they are in the form of oxyds or calces, they can eaſily be mixed with melted earths or glaſſes; and ſome of them have even great power in this ſtate to promote the fuſion of ſome of the earths, or to diſſolve them in a melting heat. They are, therefore, added to ſome of the compoſitions for making glaſs in ſome caſes, in order to make it more perfect and tranſparent, and in others, to give it colours, in the imitations of the natural gems. When metallic oxyds happen to be mixed and combined in conſiderable quantity with vitrified earths, they can be ſeparated from them by fuſion with charcoal or black flux. Thus, a piece of fine Engliſh flint glaſs, or the falſe diamonds called *Paris paſtes*, being reduced to powder, and urged with a ſtrong heat, in contact with charcoal or black flux, will be decompounded, and we ſhall find a button of lead at the bottom of the crucible.

Among the ſubſtances of the third claſs, the inflammable, ſome ſerve for the reduction of metallic oxyds. But, excepting this uſe of them, none but ſulphur, phoſphorus, and charcoal in ſome caſes, are remarkable for a diſpoſition to unite with any of the metals.

Sulphur ſhews a ſtrong attraction for moſt metallic ſubſtances, and may be united with moſt of them, readily and intimately, in the way of fuſion. And though the heat be not ſufficient to melt the metal, but only the ſulphur, if the metal be only divided into ſmall pieces, the ſulphur penetrates it, and entirely changes its appearance, examples of which ſhall be given hereafter.

In making many of theſe compounds of ſulphur and metal, a great quantity of heat is extricated from the materials, which make them become ignited, and glow as if they were inflamed. This was miſtaken at firſt for a real inflammation. The moſt remarkable of theſe experiments were made by Van Trooſtwick and Deiman. They mixed ſulphur with different metals, in a cloſed phial, or in an exhauſted tube hermetically ſealed, or in a tube filled with hydrogenous or azotic gas, or carbonic acid. With an external heat, by no means very great, the ſulphur melted, and, after ſome time, the combination with the metal took place. In that moment, the whole broke out into a bright glow, in ſome caſes brilliant, and almoſt like a real deflagration. Three parts of copper to one of ſulphur produced the brighteſt light. Lead alſo, and tin, and eſpecially zinc, produced a bright flame. *(See Note* 17. *at the end of the Volume.)*

In the new language of chemiſtry theſe compounds are called *ſulphureta*, for the Latin word, or, in the ſingular, *ſulphuretum*. And our chemiſts, who have adopted this language, call them *ſulphurets*.

Sulphur, in ſuch experiments, not only ſhews an attraction for moſt metals, but like other bodies which have a power of this kind, it is found to attract different metals with different forces. And ſome metals can be employed in many caſes to ſeparate ſulphur from others, in a certain order. When this ſeparation is performed in the way of fuſion, in a crucible, the ſulphur, uniting with the added metal, which it attracts moſt, forms a matter which flows uppermoſt; the other metal ſeparates and falls to the bottom, or forms a REGULUS. But this method of ſeparating ſulphur from metals is not the neceſſary or only method in all caſes. There are many, in which the ſulphur can be ſeparated by heat alone, and it is more uſual to expel it in that way.

Gold, platinum, and zinc, are exceptions to the general account I have given of the relation of ſulphur to metals. Sulphur cannot be made to penetrate theſe three, or unite with them, if it be applied pure, and theſe metals are in their metallic ſtate. But when ſulphur

is combined with an alkali, this compound acts much more powerly as a ſolvent, in the way of fuſion, upon metallic ſubſtances in general; and even the three I juſt now mentioned are readily diſſolved by it. The different metals, when diſſolved by this compound, unite with it with different degrees of force, in the ſame order as ſulphur does. Thus, we have it in our power to ſeparate the metals from it alſo by one another. The beſt proportion for diſſolving metals is equal parts of ſulphur and alkali.

The management of phoſphorus, in combining it with metals melted or made red hot, requires much caution. The beſt way is to cut it into bits of four or five grains weight, and keep them under water, and, when they are uſed, to take out one at a time, wipe it dry with bibulous paper carefully, and introduce it into the crucible with a long pair of pincers, plunging it to the bottom. The greater part of it is always diſſipated, but ſome combines each time. Perhaps a compoſition, which will produce phoſphorus, hard preſſed into the bottom of a crucible, would anſwer better. The crucible being made haſtily red hot, the melted metal may be poured into it, and the heat continued. The phoſphorus would thus be preſented to the metal in its naſcent ſtate, which is found to be favourable in moſt caſes of difficult combination. The fuſibility of the metal is improved by this addition.

By Pelletier's experiments *(Mem. de l'Acad. des Sciences)* 100 grains of platinum are changed into an eaſily fuſible phoſphoret, by the addition of eighteen grains of phoſphorus,—and 100 grains of gold require only four grains of phoſphorus to change them into phoſphoret. Theſe compounds, if expoſed a long time to the action of heat, burn at their ſurface until all the phoſphorus is conſumed; and the above metals remain in their ordinary ſtate.

In the experiments which have been made by mixing metals with one another, it appears that metals unite in general with one another, and this in every proportion. But there are ſome exceptions, as iron and lead, iron and mercury, lead and cobalt, nickel and cobalt, cobalt and

biſmuth. The mixtures are of different ſpecific gravity from what correſponds with the ratio of the compoſition. In general, the ſpecific gravity and denſity are greatly increaſed, ſo that in many caſes the compound is denſer than the denſeſt of the ingredients. Thus, the denſity of tin is 7363, and that of braſs is 8006. But the denſity of a mixture of two parts of braſs and one part of tin is 8916. The proportion of the compoſition ſhould have given 7793*. They are alſo more fuſible: Hence they are employed as ſolders,—for gold, we employ a mixture of gold and ſilver,—for ſilver, ſilver and mercury,—for copper, braſs,—and for braſs, another ſtill more compounded,—for either lead or tin, a mixture of both.

Mixtures of metals, in general, can alſo be calcined more quickly than the ſame metals in their ſeparate ſtate; of which you have an example in the mixture of lead and tin, which burns like a bit of turf. If you would wiſh to know the cauſe, I ſhall hazard a conjecture. I am inclined to think that this effect is produced by the chemical attraction of the metals for one another, which counteracts the coheſive attraction of each of them, and diminiſhes its force, and thereby gives advantage to another chemical attraction,—their attraction for oxygen. That their coheſive attraction is diminiſhed by their union with one another is evident, the mixture being always more fuſible than the ſeparate metals †.

The method of ſeparating metals from one another again, is very various in the different caſes, and depends upon certain particular pro-

* It is alſo an almoſt univerſal fact that the coheſion of the compound is greater than in the proportion of the compoſition. In the ductile metals, whoſe coheſions are not extremely different, the coheſion of the compound exceeds that of the firmeſt of the ingredients. Thus the mixture of twelve parts of lead with one part of zinc is twice as coherent as the zinc. EDITOR.

† Yet the mixtures are generally more denſe and much more coherent than the ingredients ſeparately.

EDITOR.

perties and differences of the metals which are to be ſeparated. Thus, in ſome caſes, difference of fuſibility is made the means of ſeparation: Thus lead is ſeparated from copper. In others, difference of volatility: Thus mercury is ſeparated from antimony. In many others, difference of ſolubility: Thus gold and ſilver are ſeparated by aquafortis, or aqua regia, or ſometimes by ſulphur; or gold and iron by ſulphur and lead.

Other ſeparating operations, which are frequently performed, depend on different degrees of their attraction for oxygen, and more or leſs diſpoſition to unite with it; that is, on a difference in their tendency to calcination. Thus lead, and moſt other metals along with it, are ſeparated from ſilver and from gold: And thus copper alſo is refined from admixture of the coarſer metals. In moſt caſes of ſeparation performed in this manner, the proceſs is called SCORIFICATION.

The mixture is expoſed to a violent heat and to a current of freſh air, which cauſes the ſurface to tarniſh, and then to gather a film or ſcale of the more calcinable metal. This is uſually blown to one ſide of the melted maſs, as it forms, by the bellows. It is ſucceeded by more; and this continues, till the leſs calcinable metal be as much purified as is poſſible by this operation. What is thus blown or raked off, is called SCORIÆ, SLAG, DROSS. It is not always a ſlag or filth,—but a portion of the metal, of the ſame purity, but no longer perfectly metallic, but a compound of the metal and the oxygen of the atmoſphere.

The ruſting of iron and other metals is a change of preciſely the ſame kind, and is produced by the ſame cauſe. It is very remarkable in iron, becauſe this metal alſo decompoſes water very faſt, and therefore ruſts very faſt in damp and warm air.

You are now informed of the general character and qualities of the metals. We muſt now attend to their natural hiſtory, or the different ſtates in which they are found in nature.

The firſt remark we have to make on this ſubject is, that few of them are produced by nature in a ſtate of purity. They are moſt

commonly found in the form of what are called ORES, which are compound minerals, in which the metal is intimately mixed with other ſubſtances, ſo as to have neither the malleability, nor the other qualities of the metals, except ſometimes a degree of the ſhining metallic appearance.

Frequently the ore is an oxyd of the metal, and only requires the operation of reduction to be performed in order to give it the metallic properties.

The ores of metals are commonly found in the veins of the hardeſt mountains, and hardeſt ſtony ſtrata. They are generally ſeparated from the rock, being intermixed in the vein with a quantity of ſpar or quartz, or ſometimes a ſofter matter. When a ſpar involves the ore, it is in ſome caſs a calcareous ſpar,—in others a fluor; but more frequently a ſulphat of barytes. When the ore is involved in quartz, it is ſometimes a pure quartz, but oftener an intermixture of quartz with ſome or ſeveral of the ſpars; and often alſo we find intermixtures of the ſpars without any quartz. Theſe matters, thus accompanying the ore in the vein, are called in general the MATRIX of the ore, and by the Engliſh miners, the RIDER. The manner in which the ore and matrix are interſperſed through the vein is altogether irregular. In ſome parts of the vein, the whole wideneſs of it is filled with ore; in other parts, with matrix alone; in others the ore and matrix are found together, in all the variety of proportions and modes of intermixture that can be imagined. Such mixtures are called *brangled ores*.

The ore being ſeparated and picked out from the matrix to be examined by itſelf, is commonly found to contain, not only the metal on account of which it is valued, but, along with it, ſome of the other metals, and a conſiderable proportion of ſulphur or arſenic, or both of theſe, and ſometimes a ſmall proportion of earthy matter.

Theſe ingredients are intimately united in the ore, that is, they are chemically combined with the metal; and the operations by which the metal is extracted are proceſſes for ſeparating theſe matters from it.

But before we can well underſtand theſe proceſſes, it is neceſſary to have ſome knowledge of arſenic. It will be found to be a metal; and it will be very convenient to make it the firſt ſubject of our ſtudy.

METALS.

GENUS I.—ARSENIC.

ARSENIC is a matter which reſembles the ſaline ſubſtances ſo much by ſome of its properties, and the metallic by others, that the chemiſts were long in doubt to which claſs it ſhould be referred. Dr. Boerhaave deſcribes it among the ſulphureous minerals, probably on account of its being often found in its natural ſtate combined with ſulphur. But when the arſenic is found pure, or is purified by art, it is widely different from ſulphur.

The nature of arſenic was very little underſtood till Mr. Macquer publiſhed ſome papers in the Memoirs of the Royal Academy, containing a number of experiments he had made on this mineral; and more lately, Mr. Scheele, of Sweden, communicated his inſtructive experiments on it to the Academy at Upſal.

The ordinary appearance of arſenic is that of a compact heavy matter, of a white or yellowiſh colour, and having the glaſſy fracture, ſometimes tranſparent, oftener of an opaque white. Expoſed to heat under the ordinary preſſure of the atmoſphere, it becomes ſoft, or approaches to fuſion, when very near the loweſt degree of ignition. But in the ſame heat alſo, it begins to evaporate in white fumes, of a ſickening heavy ſmell, thought to reſemble garlic; and is thus totally converted into vapour by degrees, without becoming perfectly fluid. The fumes, if confined and condenſed by cold, form a white powder, or chalky-like matter, which afterwards, if the veſſel

be of a proper ſhape, is ſoftened and compacted by the heat into a whitiſh glaſſy-like ſubſtance. It is always by ſublimation that it is brought to this form.

The qualities by which arſenic reſembles the metals are, 1*ſt*, Its weight. 2*dly*, A capability to be metallized, or to aſſume ſome of the metallic qualities, ſuch as the metallic opacity and bright reflecting ſurface, and a denſity or ſpecific gravity ſimilar to that of the metals. It alſo becomes a conductor of electricity, and fit for mixing intimately with the other metals, which it will not do in its ordinary ſtate.

It may be ſo far metallized by ſeveral proceſſes. Mr. Macquer deſcribes one in which this effect is produced by means of oil and ſublimation. I have ſucceeded equally well by ſubliming the arſenic repeatedly with charcoal duſt.

But one of the beſt is Scheele's proceſs, deſcribed by Bergmann. White arſenic is put into a crucible, with thrice its weight of black flux, and an inverted crucible is luted to it. The lower crucible is ſet on the fire, and ſlowly raiſed to a red heat. But the upper crucible muſt be defended from it, by means of an iron plate, having a hole exactly filled by the rim of the lower crucible. In this manner, the upper crucible will be covered within with a cruſt of regulus perfectly clean, and in a cryſtallized form. And it may be detached from it at once by a dexterous knock.

Arſenic, when thus made to aſſume the metallic appearance, is quite brittle, like ſeveral other metals, and its ſurface is liable to tarniſh, ſo that it loſes its luſtre very ſoon, if expoſed to the air. Or if we evaporate it in the open air, the vapour may be at once condenſed into white arſenic; alſo if ſublimed with fixed alkali. By theſe proceſſes, therefore, it returns immediately to its former appearance.

Theſe ſeveral particulars give us reaſon to conſider arſenic as a ſubſtance of a metallic nature; and to view it, when in its common form, as in a calcined ſtate, or as an oxyd of arſenic. But it differs

from the oxyds of the other metals, by having qualities decidedly ſaline. We have a clear example of this in its ſolubility in water, and in its action upon the alkaline ſalts, and upon nitre. The ſolubility of white arſenic in water appears, if we beat it to powder, and boil it in the water. We thus learn that it may be completely diſſolved in fifteen times its weight, and from this ſolution the arſenic may be obtained in the form of cryſtals. Arſenic unites alſo with watery ſolutions of alkalis, eſpecially cauſtic alkalis, and with lime-water, and its volatility is ſomewhat repreſſed by the union.

Its action upon nitre was thought the moſt remarkable, as it ſhews that arſenic may be employed to decompoſe nitre by expelling its acid. Equal parts of nitre and arſenic being mixed in fine powder, and expoſed to heat in a retort, the acid of the nitre ariſes very volatile and elaſtic, and of a deep red colour, and does not condenſe unleſs there be water in the receiver. It tinges water a fine blue. When the whole acid is expelled, there remains melted a white maſs in the retort, compoſed of arſenic and fixed alkali, which diſſolves in water, and eaſily cryſtallizes into very regular cryſtals. It melts in a crucible and forms a tranſparent fluid, and is very fixed, emitting no arſenical fumes; the arſenic appearing to be very ſtrongly combined with the alkali. Again, the qualities of this compound are quite different from thoſe of a compound formed by combining white arſenic with a pure alkali. It requires for its production not only the acid of arſenic, but ſo much of it as to make it acidulous and cryſtallizable. The other compound is called by Macquer LIVER OF ARSENIC. It might as well be called ARSENICATED ALKALI. It has a particular weak but heavy ſmell. If heated in a crucible, it is not fixed like the other, but emits arſenical fumes in abundance. When diſſolved in water, it will not cryſtallize, but when evaporated, becomes paſty or gelatinous. Mr. Macquer was at a loſs to explain how this happens, particularly why the cryſtallizable ſalt formed by expelling the nitric acid by arſenic ſhould be different from common arſenicated

alkali; and why arſenic does not decompoſe common ſalt, though it decompoſes nitre.

But the whole of this ſubject has been cleared up by the experiments of Scheele, who made much more progreſs in diſcovering the nature of arſenic, and has given us principles by which all the phenomena are explained. He learned, by a ſeries of inſtructive experiments, that one reaſon why the cryſtallizable arſenical ſalt, and the common arſenicated alkali, have not the ſame property, is, that the arſenic in the cryſtallizable arſenical ſalt has undergone a change from the ſtate of common white arſenic; the acid of the nitre having acted upon it as it does upon ſugar and ſome other ſubſtances, ſo as to change it into an acid. Of this he gave the moſt ſatisfactory demonſtration, by applying the nitric acid to white arſenic by other different ways, by which he changed it into an acid, which he obtained ſeparate from any other matter, and afterwards, combining this acid with the vegetable alkali in ſufficient quantity, he formed a perfectly cryſtallizable arſenical ſalt.

He contrived two proceſſes by which he changed white arſenic into an active acid. The firſt of theſe is entirely an imitation of the proceſs by which ſugar is changed into an acid, with this difference only, that ſome muriatic acid is firſt employed to diſſolve the arſenic, that the nitric acid may act on it with more advantage.

Scheele's proceſs is as follows: Into a tubulated retort, fitted with a receiver, put two parts of powdered white arſenic, and ſeven of muriatic acid, and diſſolve by a gentle boiling heat. When all is diſſolved, pour back what is in the receiver, and add three and one half parts aquafortis, and diſtil. The nitric acid riſes in red fumes, and after ſome time they ceaſe. Now add one part arſenic, and one and a half aquafortis. Red vapours ariſe again. Diſtil to dryneſs, and make the retort red hot.

In the retort you have the arſenical acid, fixed in the fire, and deliqueſcent in the air, and ſoluble in twice its weight of water.

Mr. Pelletier, however, ſays that we ſucceed equally well by uſing the nitric acid alone, in the proportion of ſix parts of the acid to one of the white arſenic. The acid comes off in red fumes of nitrous gas, and the white arſenic aſſumes the true characters of the arſenical acid (ſo it is now called). It muſt be kept a good while in a ſtrong heat, to expel all the redundant nitrous acid. (*Fourcroy* II. 507. *Ed.* 1786.)

This is an exact enough account of the phenomena, and perfectly inſtructive in the nature of the operation; but having practiſed both methods, I agree with Dr. Scheele, that his previous ſolution in muriatic acid enables the nitric acid to act on a much greater quantity of the arſenical oxyd.

The manner in which this proceſs produces its effect is ſufficiently evident. White arſenic muſt be conſidered as a metallic oxyd, containing a very moderate quantity of oxygen, and capable of a higher degree of oxydation. I always viewed it in this light; and on this principle, I explained Mr. Macquer's experiments, and the effects which it produces with nitre; a part of which is the change of the nitric acid into nitrous acid, in conſequence of the abſtraction from it of a part of its oxygen, attracted by the arſenic. In Mr. Scheele's proceſs, the nitric acid alone ſupplies oxygen to the arſenic, and thus oxydates it to the greateſt degree of which it is capable; in which high ſtate of oxydation, the abundance of oxygen which it contains gives it the qualities of an acid, and deprives it of attraction for other acids, but diſpoſes it to unite ſtrongly with alkalis. This is the proper explication of the proceſs according to the principles of the new theory; and there is an experiment deſcribed by Mr. Scheele, which gives great ſupport to the French explication of the phenomena, and eſtabliſhes it without a doubt. This experiment is made with the acid of arſenic. If ſome of this acid be put into a retort by itſelf, and expoſed to the action of heat alone, it endures a low red heat without change, or is only melted. But if the heat be increaſed, and continued, the greater part of the acid ariſes gradually into the neck of

the retort, in the form of a common white arſenic; and while this happens, a very conſiderable quantity of oxygen gas is produced or extricated from it. This is certainly a clear proof that a redundance of oxygen is contained in the acid of arſenic, conſidered merely as an oxyd, ſince we ſee that when a part of it is ſeparated by the action of heat, the acid of arſenic returns to the ſtate of white arſenic.

I may add here, the mention of one proceſs more for obtaining arſenic in the ſtate of an acid. It was diſcovered and communicated by Mr. Pelletier. He performed Macquer's proceſs, but uſed the nitrat of ammonia in place of common nitre. He thus expelled the nitrous acid, which paſſed over in diſtillation, and an arſeniat of ammonia remained in the retort. But by changing the receiver, and increaſing the heat, he was able to make the ammonia or volatile alkali ariſe in a cauſtic ſtate from the arſenical acid, which remained in the retort.

This acid is now called the ARSENICAL ACID, and the compounds it forms with other ſubſtances are ARSENIATS, in the new language of chemiſtry. Mr. Scheele made a great number of experiments with this acid, by combining it with other bodies, and inveſtigating its properties. He informs us that it has not a ſtrong taſte; that it diſſolves ſlowly in water, but may be diſſolved in twice its weight of that fluid; that in this fluid ſtate it neutralizes the alkalis and alkaline earths, and diſſolves many of the metals, or unites with them, with particular phenomena, which he deſcribes. You may ſee all this in his Eſſays, and an abſtract of the whole in Bergmann's Treatiſe on Electric Attractions; and in Nicholſon's Chemiſtry, article *Arſenic*.

Scheele found, in attempting to diſſolve ſome of the metals in the watery ſolution of this acid, that it oxydated them, and was itſelf reſtored to the ſtate of white arſenic; a proof that it does not retain the oxygen ſo ſtrongly as to prevent its communicating ſome of it to other bodies that have a ſtronger attraction for it. We have a more ſtriking proof of this in the reſult of ſeveral of the experiments Scheele

made, by cauſing the dry acid to act upon metals and other bodies. This acid is eaſily reduced to a dry ſtate, and can be melted into a tranſparent matter like glaſs. If ſome of this dry acid is beaten to powder, and then mixed with dry charcoal in powder, or with filings of different metals, and theſe mixtures are heated, there is, in many caſes, a ſtrong deflagration, ſuch as is produced by nitre with the ſame ſubſtances; and the acid is in a moment changed, partly into white arſenic, and partly into pure or metallic arſenic, both of which are ſublimed.

Mr. Scheele diſcovered that Mr. Macquer's cryſtallizable arſenical ſalt, prepared with nitre, is a compound not exactly neutral, but is a little acidulated by a ſmall ſurplus of the acid of arſenic, and when it is made exactly neutral, it will cryſtallize, but is deliqueſcent. And he explains how it is formed in the proceſs with nitre.

When arſenic is in its ordinary ſtate of white arſenic, it is ſoluble, in ſmall quantity, in a variety of fluids. Boiling water, I obſerved before, diſſolves one-fifteenth or one-twentieth. Spirit of wine alſo diſſolves a little of it, and even oils. Aquafortis, or diluted nitric acid, alſo diſſolves it with difficulty, but changes it more or leſs into acid of arſenic. The readieſt ſolvent is muriatic acid, which diſſolves oxyds of metals in general better than other acids do. It forms a compound, which can be diſtilled or ſublimed; and ſometimes condenſes like oil. Fourcroy ſays that calx of arſenic, that is, white arſenic, will not afford this oil, but that it is eaſily got from one part of metallized arſenic and two parts of ſublimate of mercury,—the mercury being revived.

Arſenic has a diſpoſition to mix in ſmall quantity with earthy bodies in a vitrified ſtate, or to act on them; and this is one of its uſeful qualities, a good deal of it being employed by the manufactures of glaſs. White enamel is made with it, with which Delft ware is glazed; and alſo all the pretty ornaments, which were formerly twiſted in very beautiful ſcrolls in the ſtalks of wine glaſſes, &c.

Sulphur alſo can be combined with arſenic, as with the metals, and the compound is more fuſible than arſenic alone. The fuſibility is increaſed by increaſing the quantity of the ſulphur, and the colour is yellow, orange, or deep red. It is called *yellow arſenic*, and *orpiment*, (the *ſandarac* of the ancients) and *realgar*. The dangerous powers of the arſenic are conſiderably abated in theſe compounds. Hence it is that the Chineſe, and other Orientals, form realgar into medical cups, and employ as a purgative, lemon juice which has ſtood ſome hours in them. The ſulphur can be ſeparated again by ſublimating the compound with potaſh, and by other proceſſes.

Arſenic can eaſily be united with the metals in their metallic form, but only when it is itſelf metallized. The common way is to mix it with materials that will metallize it, and apply this mixture to the metal, with a proper heat, in the form of vapour. It whitens them, and makes them brittle. One of the diſtinguiſhing qualities of arſenic is that of uniting, when heated in any inflammable mixture, with ſome of thoſe ſubſtances, and flying off with it. Hence it is reckoned a purger or purifier of glaſs; and is a powerful calciner, or ſcorifier of the metals. But it is no leſs hurtful, on the other hand, in metallurgy, by carrying the metals off with it; to prevent which is one of the great operations upon the ores in metallurgy.

Origin, or Natural State of Arſenic.

Arſenic is ſometimes found pure, or in the form of ſolid metallic arſenic, but oftener more looſely concreted, like a grey or black friable mater. But pure arſenic in any ſhape is rare; though, in the ſtate of combination, there is plenty of it in many of the ores of metals, eſpecially thoſe of cobalt, copper, ſilver, and iron. In the white pyrites, it is known by the garlic ſmell when ſtruck. It is moſt plentiful in this mineral, and in the ore of cobalt. Exiſting in ſo many compounds, from which it may be expelled by heat, it abounds in volcanic countries. In Solfatara, it contaminates every volatile ſubterraneous pro-

duction, and is found in many of thoſe forms into which we bring it in the operations of our laboratories.

There are alſo natural compounds of arſenic and ſulphur, called *orpiment* and *zarnic;* but the greateſt part of the orpiment in the ſhops is artificial. Arſenic for the uſe of the arts is prepared chiefly from cobalt ores and white pyrites, in Saxony, as a ſecondary buſineſs only, in the manufacture of zaffre and ſmalt. The arſenical fumes are collected in chambers, which act as ſubliming veſſels, as we ſhall ſee preſently. It is uſeful in the manufacture of glaſs, and in dying. Such, therefore, is the hiſtory of arſenic conſidered as an object of chemiſtry.

The knowledge of this mineral is neceſſary to the phyſician, both on account of its great efficacy in the cure of ſome diſeaſes, when it is properly uſed, and alſo on account of its noxious powers, in conſequence of which, it is ſometimes given with the moſt criminal intentions. In ſuch caſes, the phyſician is called in to aſſiſt in forming a judgment whether arſenic has actually been given or not.

It has long been one of the ſecret remedies employed by ſome empirical practitioners,—externally, for the cure of cancers, and other obſtinate ulcers; and internally, for the cure of intermittent and other fevers. And the ancient phyſicians, in ſome of their preſcriptions, employed ſome of the natural compounds of arſenic and ſulphur. In later times, the firſt example of its being publicly recommended as a remedy for the cure of fevers, is in the Memoirs of the Academy at Mentz, for the year 1757, by a Dr. Jacobi. But we are moſt indebted to Dr. Fowler for his late accurate trials of it. They were conducted in the moſt judicious manner, to ſecure exactneſs in the doſe, and to aſcertain the efficacy of the medicine; and they are related ſo fully and circumſtantially, that they give complete information and ſatisfaction, with reſpect to every particular that is moſt intereſting in the uſe of this powerful remedy. A better plan cannot

cannot be contrived for aſcertaining the powers and uſes of the medicines we employ.

Phyſicians and ſurgeons are ſometimes called upon, in caſes of ſuppoſed murder by arſenic, to give their opinion; and the queſtions commonly put to them are theſe:

1. Whether the appearances or ſymptoms obſerved in the dying and dead perſon give reaſon to conclude that they were killed with arſenic?

2. Whether certain drugs or powders which were given to the dead perſon, or mixed with his food, and a part of which are committed to the phyſician to be examined, be arſenic, or contain arſenic?

It is neceſſary to be cautious in giving our anſwer to the firſt queſtion, which ſeldom admits of a perfectly deciſive anſwer, if the preſumption of poiſon reſts on the ſymptoms alone; the ſymptoms produced by arſenic being not unlike to thoſe which appear in ſome diſeaſes, ſuch as the cholera. But theſe ſymptoms may add to the proof which may ariſe from other evidence.

The ſymptoms produced by a dangerous doſe of arſenic begin to appear in a quarter of an hour, or not much longer, after it is taken. Firſt, ſickneſs, and great diſtreſs at the ſtomach, ſoon followed by thirſt, and burning heat in the bowels. Then come on violent vomiting, and ſevere colic pains, and exceſſive and painful purging. This brings on faintings, with cold ſweats, and other ſigns of great debility. To this ſucceed painful cramps, and contractions of the legs and thighs, and extreme weakneſs, and death.

After death, the inteſtines are found inflamed and corroded; and ſometimes inflammations and eroſions of the anus happen before death.—

In examining the dead body, we muſt take care that we be not deceived by the diſſolution of the ſtomach by the gaſtric liquor, and account it an indication of arſenic.

If we actually find arſenic in the ſtomach or inteſtines, or in the drugs or other ſuſpected matters which were given to the dead perſon, we can give a deciſive anſwer to theſe two queſtions. But we muſt make ourſelves ſure that what we judge to be arſenic be really ſo.

We muſt, therefore, take care to be well acquainted with the qualities of arſenic, by which it is diſtinguiſhable from all other ſubſtances. And its diſtinctive properties are theſe:

1*mo*, It is a heavy ſubſtance, which may therefore be ſeparated by ſkilful elutriation from animal or vegetable matter with which it may happen to be mixed in the bowels or in the drugs. Elutriation is commonly performed with water; but if the arſenic is mixed with oily or reſinous drugs, it may be performed with alcohol. In examining the dead body, therefore, it may be proper to waſh out the whole contents of the ſtomach and bowels into a baſon of water, and then, by careful elutriation, to try if any arſenic can be found in them. And in examining the drugs, if they are a mixture of different ingredients, we muſt dilute or diſſolve them, by grinding them a little with water or ſpirits, and then elutriate.

2*do*, Arſenic, beſides being a heavy ſubſtance, is volatile. When heated on a red hot iron, it evaporates totally before it be red hot, and goes off in white ſmoke.

3*tio*, It is eaſily metallized by mixing it with three times its weight of the black flux, and heating the mixture in a tube.

4*to*, In this metallized ſtate, it eaſily penetrates copper, when aſſiſted by heat, and gives to the copper a whitiſh colour like that of lead or tin. It muſt be made of a dull red heat. This will completely diſſipate corroſive ſublimate, or other things which can whiten copper.

5*to*, In its metallized ſtate, if it be ſuddenly heated to a ſufficient degree on a red hot iron, it takes fire, and burns with a flame, from which ariſes a ſmoke, which is white arſenic. Or, if the iron be not ſufficiently hot to make it take fire, it ſimply evaporates, and gives

vapours which have an odour like that of garlic. The ſame odour is perceived, if we mix white arſenic with an equal weight of charcoal duſt, and throw a little of the mixture on a burning coal, or on iron ſtrongly heated, ſo as to ſet the charcoal duſt on fire. This experiment has been often miſunderſtood.

Having had occaſion ſome time ago to exerciſe myſelf in theſe experiments, and to try with how ſmall a quantity of arſenic they might be made, I found I was able, by means of a ſmall tube, to get metallized arſenic from one grain weight of white arſenic; and with this metallized arſenic I made the other experiments.

Remedies to ſave, if poſſible, the life of a perſon who has taken Arſenic.

The firſt ſymptoms which the arſenic produces ſhew plainly that for ſome time after it is taken, it acts on the ſtomach and inteſtines, as an highly irritating, inflammatory, corroſive ſubſtance. But if the patient ſurvives the firſt violent effects, the poiſon being evacuated out of the bowels, the ſymptoms which appear afterwards are thoſe of exceſſive debility, and a great irritability of the inteſtinal canal, and of the whole ſyſtem. The degree of debility is particularly remarkable. It not only is evident from the languor, diſtreſs, and feebleneſs of the patient, but alſo from the ſtate of the pulſe. I never felt a more feeble pulſe than that of a perſon in this ſituation. All this is attended with a ſort of paralytic affection of the limbs, and a degree of maraſmus.

The methods commonly recommended to ſave the life of the perſon in the firſt of theſe ſtates is, to give plenty of milk and oil, as obtunding remedies, and which help to waſh and carry off the arſenic out of the inteſtines, while vomiting and purging continue.

A better practice, however, might be ſubſtituted for this. Arſenic being a heavy ſubſtance, is not eaſily waſhed out by milk, and it may probably coagulate the milk by its acidity. Oil will not mix with it after it is wet. I ſhould prefer mucilage, taken in large quantities,

and if it do not paſs off quickly, I would promote its paſſage by means of a purgative, ſuch as Glauber's ſalt, or ſal catharticus amarus. A friend of mine once gave whites of eggs with ſucceſs.

In the ſecond ſtage of the diſorders produced by arſenic, which is commonly of long duration, a mild diet of milk is proper. The frequent uſe of opiates, to relieve from conſtant diſtreſs, and after ſome time electricity, are very ſerviceable. De Haen found electricity one of the beſt remedies for the cure of the diſorders occaſioned by lead. Mineral waters have been recommended, eſpecially the ſulphurous waters; and to imitate theſe, hepar ſulphuris diſſolved in water may be employed. But this practice is founded upon project and ſpeculation, not upon experience.

Metallurgy.

The nature of arſenic being now explained, you are prepared to underſtand the operations by which metals are extracted from their ores.

The firſt of theſe operations is to ſeparate the ore as much as poſſible from the ſpar, or other ſtony matter that accompanies it.

When the ore is found in the vein in large maſſes, or fills up the whole, or a conſiderable part of it, many feet wide, which is often the caſe, it may be cut out tolerably clean, or free from the adhering matrix; or, after it is taken out of the vein, any part of the matrix that adheres to it may be ſtruck off. But, in many mineral veins, the ore is interſperſed through the matrix in very ſmall maſſes, and ſo entangled in it that they cannot be ſeparated in this way.

The expedient to which the metallurgiſts have recourſe in this caſe is, to take advantage of the great difference of ſpecific gravity between the ore and the ſtony or earthy matter in which it is involved. They break or bruiſe the whole into ſmall fragments, like gravel or ſand,

and then expoſe it, upon a board or ſhallow trough, to the action of a ſmall ſtream of water running over it with moderate velocity, while the broken ore is gently ſtirred at the ſame time. The moving water carries along, and waſhes away the earthy and ſtony particles before it can move the heavier particles of the ore. This is called *waſhing*, or *dreſſing* the ore; in Latin, *elutriatio*. There are many ingenious and ſimple ways of performing this proceſs, of which you will find a diſtinct account in *Agricola de Re Metallica*. This proceſs is eaſy, when the ore is found in ſand or earth, which is often the caſe with regard to ſome metals; but others are, in general, found in a ſolid matrix, not diviſible by water alone, or diffuſible in it. It muſt therefore be divided, or broken down mechanically. This is done, in ſome caſes, by flat iron mallets, or by means of ſtamping mills. It often happens too, that the matrix is much harder than the ore, and then mechanical pulverization alone will not anſwer. This difficulty can often be obviated, by burning or calcining the mineral with a briſk fire of ſhort continuance, and throwing water on it while red hot. The effect of this upon the ſtone or matrix is great, if it be calcareous or ſparry, but leſs, yet very conſiderable, even upon quartz. Thus, therefore, this ſort of ore, in a reduced ſtate, can be pulveriſed and dreſſed with ſucceſs. But, although the ſkill and addreſs with which this art is practiſed enables the miners, in many caſes, to ſeparate the ore from very great quantities of the ſtony matter, ſome ores cannot be powdered and waſhed without loſs of ſome of the metal; and, where circumſtances are unfavourable, a great quantity is loſt, in conſequence of its being broken ſo ſmall that the water carries it away. Therefore, in ſuch caſes, it is found more expedient to procure the ſeparation by bringing the whole into fuſion. This is much practiſed in Germany, in the management of ſome ores, but very little, if at all, in this country. They perform the fuſion in the ordinary furnace, and mix the ore and ſtones of different kinds. When the whole is thus haſtily melted, the ore, as it conſiſts of metallic ſubſtances and ſulphur or ar-

ſenic in an uncalcined ſtate, ſeparates from the melted earthy matter, and is collected at the bottom. It alſo undergoes ſome change by this haſty fuſion; ſome of the ſulphur and arſenic is diſſipated; and ſome of the more calcinable metals are calcined and mixed with the ſcoriæ. But it ſtill retains ſo much of its impurities, that it may be conſidered only as a ſort of ore. This operation is called *crude melting*, or *crude fuſion*. It is not for all ſorts of ore, but only for thoſe which are entangled with the matrix, ſo as not to be conveniently ſeparable by waſhing, but capable of perfect fuſion by proper additions.

When the ore is freed from all the earthy matter, which can by this or the former operation be ſeparated from it, the next ſet of operations which it undergoes are intended for ſeparating the ſulphur, or arſenic, or both, if it contains them. It is neceſſary to ſeparate theſe with milder heat, and the action of air, before it be melted, on account of their ſtrong adheſion, and their occaſioning much loſs of the metal, by carrying ſome of it off in vapours, and alſo occaſioning more to calcine and mix with the ſcoriæ. The ore is, therefore, firſt expoſed to the action of a gentler red heat, long continued, which is called *roaſting* of it *(uſtulatio)*, moſt commonly in heaps, with fuel intermixed, in the ſame manner as bricks are burned. Sometimes this is done in a furnace of a particular ſtructure, contrived with great ingenuity, for collecting and preſerving the arſenic, and even ſome volatile and very calcinable metals, contained in the ores of that metal for which the whole proceſs is chiefly carried on.

Some ores require ſeveral repetitions of this proceſs of uſtulation before they are ſufficiently freed from volatile matters.

When theſe operations are finiſhed, the metal remains more or leſs calcined, and therefore requires, in the next place, that the operation of *reduction* be performed. This is done in particular furnaces, of different ſtructures, according to the degree of heat neceſſary, and the mode in different places. A conſiderable variety are deſcribed by Agri-

cola, from which thoſe at preſent in uſe do not differ eſſentially, except in the very large ſize, to which ſome are now carried. In theſe, the ore is melted in contact with the fuel, that the whole of the oxygen and ſulphur, ſtill combined with the metal, may be abſorbed by the burning fuel, and carried off in the form of carbonic acid and ſulphurous acid. Proper fluxes are alſo added for any earthy matters that ſtill remain; and alſo earths, and even metals, are ſometimes added, which ſtill more completely abſorb the ſulphur. The deſired metal, thus freed from extraneous matters, collects at the bottom, and the earthy and ſulphurated matter floats above as a ſcum or ſlag. This is let off, in ſome caſes, by a tap-hole, at ſome diſtance from the bottom. In other caſes, it is drawn off with rakes, or driven off by the bellows. The melted metal is then let out by a lower tap-hole, in the great furnaces, or lifted out of the ſmall furnaces with ladles. The ſlag is, in many caſes, rich in ſome other metal, which has been ſcorified in this proceſs for the principal metal, and is worked off for it in other furnaces.

The next operation generally is *refining* the metals.

Many ores either do not require, or do not admit of all theſe operations, but agree beſt with the omiſſion of ſome, and variation of others, as I ſhall obſerve more particularly hereafter.

In treating this ſubject, it is uſual to mention the art of ASSAYING ores and metals, which is an aſſiſtant to the art of ſeparating metals from their ores, and of refining them. The art of aſſaying is the art of performing all the operations I have been deſcribing, upon ſmall quantities of the ſubjects, and in a very ſhort time, in order to judge of the nature of an ore, the metals it contains, the beſt manner of working it, and the profits it will yield. It is alſo neceſſary to the art of coining, and to the regulation of the fineneſs of plate.

The practice of this art requires the greateſt degree of attention and accuracy in the artiſt, to avoid the ſmalleſt loſs of any part of the ſubject he is working upon, by any miſmanagement; as a ſmall loſs of

this kind would occaſion very great errors in the calculations of the profitableneſs of working the ore, or of the value of the ſubject of the aſſay.

To deſcribe the art of aſſaying would require much more time than can be ſpared in an elementary courſe of chemiſtry. I muſt, therefore, refer you to thoſe authors who treat it in the moſt judicious manner. I need ſcarcely name another, after mentioning Cramer's *Ars Docimaſtica*. He was a moſt excellent chemiſt; and his work is complete with reſpect to the *docimaſia viâ ſiccâ*. Of late, however, another method of aſſaying, *viâ humidâ*, has been much cultivated. The beſt writers on this aſſay are Bergmann, Fordyce, and Woulfe. Mr. Fordyce was, I believe, the firſt who thought of this as a complete mode of aſſay. It certainly gives a more complete analyſis than the dry way; but is too tedious for the neceſſary diſpatch of buſineſs.

The dexterous uſe of the blowpipe is of unſpeakable ſervice in the examination of ores and minerals. By a proper application of the flame, we can either burn off all inflammable matter, or we can aſſiſt the ſubſtance on which it is directed to unite with, or act on the inflammable matter of the charcoal on which it lies. When we envelope the body in the blue point of the interior flame, the exterior flame keeps off the air, and allows the combination with the charcoal to take place, and to continue. But by directing the very point of the flame on the body, we conſume all inflammable matter by the application of unſaturated air to it. Therefore, when we operate on metallic ores, we can, in an inſtant, either calcine or reduce the metallic part.

The operations of metallurgy, in the great way for commerce, are too various, and too complicated, to be deſcribed and explained in an elementary courſe of chemiſtry, and at any rate, cannot be introduced at preſent, becauſe, ſince the propriety of them depends on the nature of the various metals contained in the ores, which is yet un-

known to you, you could not underſtand the moſt perfect account of them. On this ſubject, which comprehends almoſt the whole of our ſcience, you muſt conſult the *Ars Metallica* of Agricola, and the *Metallurgy* of Schlutter. Of this laſt work, which is a very excellent performance, Macquer has given very good extracts in the articles of his chemical dictionary.

The very ſhort account which I have now given you of the art of metallurgy was a neceſſary preamble to the philoſophical ſtudy of the different metals, conſidered as the ſubjects of chemical ſcience. It was, I confeſs, ſomewhat irregular to include arſenic, one of their number, in this preamble; but ſo many of the metallurgic proceſſes are performed in order to get rid of this troubleſome ingredient, which is not ſought for on its own account, nor was even thought metallic, till of late, that we could not proceed intelligibly without a certain knowledge of its peculiar qualities.

I ſhall now enter profeſſedly on the inveſtigation of the peculiar properties of the different metals, following, in each, the method of treatment already familiar to you, and I ſhall conclude each article with a ſhort account of its natural ſtate, and the metallurgic proceſſes for obtaining it in its pureſt metallic form;—proceſſes which, although ſomewhat alike in all, muſt yet be modified, in compliance with the peculiarities in the chemical properties of each.

In proſecuting this important part of the courſe, which, with pharmacy, conſtituted almoſt the whole of ancient chemiſtry, I ſhall take the metals in that order in which I think their properties moſt eaſily explained. This is almoſt the ſame with that of their diſpoſition to be calcined or burned, which are equivalent changes of their appearance and properties. Of all the metals, gold, or platinum, is the moſt tenacious of the metallic form; and, on the other hand, the moſt calcinable or combuſtible of them all is the mineral called *manganeſe*, now found to be a metal, having ſingular properties, which are moſt

curious in themſelves, and are of great aſſiſtance to us in explaining and eſtabliſhing ſome of the leading doctrines of chemiſtry.

For theſe reaſons, manganeſe ſhall take the lead; and I ſhall conſider the metals in the following order. Magneſium, iron, mercury, antimony, zinc, biſmuth, cobalt, niccolum, lead, tin, copper, ſilver, gold, and platinum. Having already conſidered arſenic I now proceed to

GENUS II.—MAGNESIUM.

This is by no means a rare production; and it has been long in our hands, and much employed, although its nature is but lately underſtood. It often occurs in our mines: Few are altogether without it; and ſome contain very great quantities. Its common appearance is a hard ſubſtance, of a grey colour, and frequently of a chocolate colour, which may almoſt be called black. It is eaſily known by its ſoiling the hands exceſſively, like a dark brown greaſy pigment. The Germans, for this reaſon, call it *braun ſtein*. It may be ſeen at every potter's kiln, where it is uſed for giving the black, or dark purple glazing to the very coarſeſt of our earthen ware. It is very abundant in Derbyſhire, in a foſſil called *black wad;* and was, for a while, ſold for a coarſe pigment, till the knowledge of ſome of its remarkable properties put a ſtop to its employment in this way. For its other varieties, I refer you to Kirwan's or Cronſtedt's *Mineralogy*. It is employed for tinging glaſs purple, and to compoſe the enamels that are uſed in decorating the glazing of ſome earthen ware, ſuch as the tiles with which our chamber fire-places were formerly lined,—and indeed for the figures on much of the common kinds of Delft ware. It is alſo uſed for a purpoſe which ſeems the oppoſite to theſe, namely, for clearing glaſs of all colour, eſpecially that green colour with which it is generally tainted.

The chemiſts knew nothing farther about manganeſe. They ſup-

poſed it to be an ore of iron, but of a bad quality, becauſe little or no iron is obtained from it. Some, however, have long ſuſpected that it was a metallic calx, of a peculiar kind; and by ſuch curious naturaliſts, it has been a good deal tortured. It has been deſcribed under various names,—*black wad* in England; *braun ſtein* among the German miners; in Latin it has been called *manganeſium*, *magneſium*, *magneſia nigra*, &c. Chemiſts have now agreed to call it MAGNESIUM; and under this name I ſhall ſpeak of it.

It is needleſs to mention the many vague and random experiments which were made on it during the nonage of chemical ſcience. We never had any clear notion of its properties, till Mr. Scheele took it in charge; and he has given an account of his examination in an admirable paper, read to the Royal Academy at Upſal, and printed in the Tranſactions, in the Swediſh language, from which it was ſoon tranſlated into German, and thence into French, and here into Engliſh. Whatever is the ſubject of Mr. Scheele's examination, he ſhews in his inveſtigation ſuch an uncommon degree of induſtry, of ingenuity, and of chemical ſkill, that you cannot have a better pattern for the proper conduct of chemical reſearches. I have often quoted this excellent author, and ſhall yet often refer you to his ingenious diſſertations. To him, as I have ſaid, we owe our firſt clear knowledge of this mineral. But it was Dr. Gahn, another chemiſt of the ſame academy, who firſt demonſtrated magneſium to be a metal, by reducing it completely to the ſtate of a hard and brilliant metal, by treating it properly with charcoal in a moſt violent and long continued heat.

Magneſium has no volatility in its natural ſtate. But, if expoſed for a long time to a red heat, it ſuffers a conſiderable loſs of weight. If this be done in a proper apparatus, we obtain from it a prodigious quantity of aëreal matter. This, when examined, is found to be vital air, of the pureſt kind,—when the magneſium itſelf is pure, which, however, is rarely the caſe. It is frequently tainted with iron, and

with arſenic, and with earthy matters; carbonic acid, therefore, often taints the aëreal product. Many chemiſts affirm alſo, that the pureſt manganeſe always emits azotic gas in the beginning of the experiment, and that a ſtronger heat is neceſſary for detaching the vital air. This, however, is its moſt abundant product; and it is at preſent the ſubſtance from which it is obtained for moſt of our experiments, and alſo for moſt important purpoſes in the arts.

This effect of heat on magneſium induces us to conſider it as a metallic oxyd, ſimilar to many others very familiar to the chemiſt; but it differs from them in a remarkable circumſtance. When this great quantity of vital air has been obtained from it, the remainder is of a much brighter colour than before; and in ſome caſes, in which we have expelled the greateſt quantity poſſible, it becomes perfectly white. The oxyds of other metals are always of the deepeſt colour when the greateſt quantity of oxygen has been taken from them.

When magneſium has been thus deprived of ſome oxygen, it ſpeedily recovers it again, merely by expoſing it to the common air. The rapidity with which it attracts the oxygen of the atmoſphere, is indeed very remarkable; a few hours will ſometimes ſuffice for reſtoring it to its former ſtate of repletion with oxygen; and in thus recovering its natural ſhare, it alſo recovers its natural colour, and becomes black as before.

When oxygen, already in a gaſeous form, is made to combine with other matter, there is always an extrication of heat and light. The preſent caſe is no exception, when circumſtances are favourable. When a conſiderable quantity of magneſium, which has been deprived of its abundant oxygen, is expoſed to the air in an extenſive ſurface, it recovers it with heat, and even incandeſcence. It cannot flame, becauſe it is not volatile.

This ſurpriſing property of magneſium occurred to Dr. Scheele in the courſe of his examination. Having expoſed a quantity of black magneſium to a red heat for a quarter of an hour in a phial, the mouth

of which was ſtopped with a piece of chalk, he turned it out, ſtil white on a piece of paper. It ſoon deflagrated, and it became black. If it was kept ſhut up till quite cold, and then turned out on a hot plate, it immediately became red hot. It does ſo in an inſtant, if looſely poured into a jar containing vital air, and may be ſeen white, as it enters this air, and black before it reach the bottom, when the jar is tall.

Theſe and other analogous phenomena made Dr. Scheele ſuppoſe that black manganeſe was a ſubſtance which had attracted phlogiſton; and this opinion, natural to a chemical philoſopher of that day, was confirmed by a ſeries of the moſt curious experiments, made by treating magneſium with the more active chemical ſubſtances. Of theſe the acids afford the moſt inſtructive phenomena, which I ſhall take pretty much in the order in which they occurred to Dr. Scheele, led by the train of his ſpeculations and conjectures, preſuming that the procedure of ſuch a mind will not be unpleaſant to you.

Magneſium, in its natural black ſtate, diſſolves in the acids but ſlowly, and with difficulty, and in ſome it does not diſſolve at all. I lately had occaſion to remark that the metals, when very much calcined, that is, when combined with a great quantity of oxygen, have their attraction for acids greatly diminiſhed; and there are ſeveral examples of their being thereby rendered altogether inſoluble. Manganeſe in its natural ſtate is ſimilar to thoſe oxyds; but if ſome vital air be expelled from it by heat, or if it be taken in its white ſtate, it will be diſſolved in ſuch as did not act on it in its black ſtate.

The ſulphuric acid is altogether inactive on it in its natural ſtate; but if it be treated with charcoal, and made by heat to give out a prodigious quantity of carbonic acid,—and if it be then put into ſulphuric acid, it diſſolves very readily. It is pretty much the ſame with reſpect to the other acids. If ſtrong ſulphuric acid be boiled for ſome time on black manganeſe, a ſmall portion is diſſolved, the acid having expelled ſome oxygen by the aſſiſtance of the great heat.

If precipitated by a cauſtic alkali from any of thoſe ſolutions, it is always white, or at leaſt, is far from its ordinary dark colour,—and in this ſtate it diſſolves readily in all the acids.

Theſe facts make it clear that the ſolubility of magneſium in the perfect mineral acids depends greatly on its degree of oxydation. It is inſoluble when the oxygen is abundant, but ſoluble when this is diminiſhed to a certain degree: What proportion of the abundant oxygen muſt be abſtracted has not yet been aſcertained with preciſion. It appears alſo, that charcoal has a greater attraction than magneſium for oxygen,—at leaſt when its attraction is aided by the volatility of oxygen augmented by heat. But there are ſome other circumſtance in the relation of magneſium to the acids, which are not a little myſterious and puzzling. Although the ſulphuric acid does not diſſolve manganeſe, the ſulphurous acid diſſolves a part of it very readily,—yet the ſalt is not of the kind we expect from ſuch ingredients,—it is a permanent ſulphat of magneſium,—and if we precipitate the magneſium by an alkali, it is in its deoxydated ſtate. Therefore the acid in it is not the ſulphurous but the ſulphuric, having its full ſhare of oxygen.

Perhaps this phenomenon explains the ſolubility. The black manganeſe may be ſuppoſed to have a portion of its oxygen redundant, while the ſulphurous acid is deficient in oxygen. The attractions may be ſuppoſed nearly equal, ſo that when the acid has taken as much of the redundant oxygen as completes it to the ſtate of ſulphuric acid, this acid diſſolves what part of the manganeſe has been ſo much deoxydated as to become ſoluble. This explanation is rendered very probable by the ſubſequent experiments of Dr. Scheele.

An ounce of aquafortis and twenty grains of manganeſe being mixed, no ſolution follows. But upon adding about a drachm of vinous ſpirits, and making the mixture lukewarm, there is an effervеſcence and eruption of nitrous gas,—and the manganeſe now diſſolves completely; and after this, four additions, of twenty grains each, will be

diſſolved. The mixture grows very hot. I imagine that the effervescence is chiefly produced by the carbon of the alcohol, and partly perhaps by the oxygen gas or vital air.

Mr. Scheele effected the ſolution of manganeſe in nitric acid in different ways,—by means of ſugar, or eſſential oil, &c. But a much more curious means occurred to him. He, and indeed other chemiſts before this, had noticed the remarkable effect of the ſun's light, in blackening the vitriolic acid, and in cauſing the pale nitric acid to become ruddy and fuming; and they attributed this to the introduction of phlogiſton, becauſe ſulphur was produced, and becauſe ſugar produced the ruddy fumes. Obſerving that ſugar enabled the nitric acid to diſſolve manganeſe, he tried whether the ſame effect might not be alſo produced by the ſun's light. Pouring half an ounce of nitric acid on twenty grains of manganeſe, and agitating the mixture, it continued quite inactive. He then ſet the matraſs in the ſtrong light of the ſun, on midſummer day, and in an hour's time, he had a perfect ſolution. He added twenty grains more, which were alſo diſſolved,—and continued adding till no more was taken up. He precipitated the manganeſe by means of a diluted ſolution of potaſh,—it was perfectly white. He conſidered it as manganeſe united with phlogiſton and fixed air. He mixed it with one-fourth part of nitre, and gave it a red heat in a retort, and got a quantity of nitrous gas. The nitre in the retort was alkalized.

Reflecting on theſe experiments, ſhewing the ſolubility of manganeſe in pale nitric acid by means of inflammable bodies or light, we have reaſon to conclude, that theſe bodies act firſt on the nitric acid, producing their uſual effects, viz. abſtracting or expelling a part of its oxygen, and changing it into a more volatile acid. It then becomes a ſolvent for the manganeſe.

But in whatever way we diſſolve it, we always find it in a deoxygenated or white ſtate, when we precipitate it with an alkali; and in

this ſtate it will diſſolve without difficulty, if done ſoon,—but if allowed to remain ſome days, it becomes black and inſoluble.

I have called a portion of the oxygen combined with manganeſe *redundant*. It is unqueſtionably provided with it, to the very point of ſaturation; and what has been laſt accumulated ſeems to be weakly united: For it is eaſily abſtracted from it by other bodies,—particularly by ſome inflammable ſubſtances. Of this we have a remarkable example, by mixing a quantity of black wad in powder, with as much boiled lintſeed oil as will juſt make it ſtick together in clots. If this mixture be made up into a heap, and ſet in a warm place, as on the hearth, before a glowing fire, ſo as to become lukewarm, it will take fire in about half an hour; and it deſerves remark, that this combuſtion is accompanied by a ſmell by no means offenſive, though very ſtrong. It is ſomewhat aromatic, and altogether unlike the ſmell of lintſeed oil burning with a ſmothered heat. I imagine that the redundant oxygen is combined with the oil, which we know to have a conſiderable attraction for it, and to abſorb a great deal from the atmoſphere. This combination is accompanied by the extrication of heat, in the ſame manner as in the mixture of nitric acid with ſuch oils. Only, the oxygen of the magneſium is probably neither ſo copious nor ſo looſe as in the nitric acid. During this combuſtion, the carbon and hydrogen of the oil fly off with the oxygen of the manganeſe, forming carbonic acid and water; and the manganeſe ſoon recovers its abundant ſhare of oxygen again, by expoſition to the atmoſphere.

The mixture of manganeſe with muriatic acid exhibits phenomena ſtill more remarkable, and indeed is one of the moſt curious facts in chemiſtry. When the common muriatic acid is applied to black manganeſe, it diſſolves it, ſlowly indeed, but eaſily, and in conſiderable quantity, and needs no addition of inflammable matter. But it adheres ſo feebly, that even water ſuffices for precipitating the greateſt part of it, in its ordinary form. This eaſy ſolution made Dr. Scheele ſuſpect that muriatic acid, in its ordinary ſtate, contained ſome phlogiſton, na-

turally combined with it, which reduced the manganeſe to a leſs calcined ſtate, and thus diſpoſed it to diſſolve ſo eaſily in the acid. This conjecture was confirmed by the phenomena which the mixture preſented when a gentle heat was applied to it. He learned that a part of the acid is greatly changed from its ordinary ſtate, and is gradually converted into a penetrating vapour, of a yellow colour, and moſt inſupportable ſuffocating ſmell.

This gas is one of the moſt remarkable objects in chemiſtry. It is with difficulty obtained in any other form than that of an elaſtic aëreal matter, having ſcarcely any attraction for water. The ordinary muriatic acid gas has a ſtrong attraction for water, and is, by this means, obtained in the ordinary form of a watery acid: But when diſtilled from black manganeſe, it will ſcarcely unite with water, and unites only in very ſmall quantity, and is eaſily ſeparated again, or rather is with great difficulty preſerved in a combined ſtate. A freezing cold, indeed, will condenſe it into a ſort of ſoft or ſolid matter, but when the cold abates, it immediately reaſſumes the gaſeous form. It may, however, be condenſed, in conſequence of its attraction for other ſubſtances, ſuch as the alkaline ſalts, and eſpecially the inflammable ſubſtances, ſuch as oils, animal and vegetable ſubſtances, ſome bitumens, and metals in their metallic ſtate. It acts ſo ſtrongly on many of thoſe ſubſtances as to inflame them. Thus phoſphorus, plunged into this gas, takes fire immediately. Sulphur alſo, if hot enough to begin to melt, inſtantly takes fire. Even charcoal, if in exceeding fine powder (ſuch as may be got by waſhing the nitre out of gunpowder) when made warm, and thrown looſely into this gas, inſtantly kindles. I have met with ſome aſſertions that the vapour of alcohol alſo takes fire in it, but I have not found it ſo, either with the vapours of alcohol, or that of the vitriolic æther. Nor have I found that it kindles ſome of thoſe compound hydrogenous gaſes which are ſo ready to take fire. The abominably fœtid gas, containing phoſphorus and hydrogen, fires pretty readily in this muriatic gas,

but requires particular management, and a particular ſtate of the ingredients, which you will underſtand as we proceed.

Moſt of theſe curious facts occurred to Dr. Scheele, although in a more complex manner, becauſe he was not thoroughly inſtructed in the nature of this vapour. But he ſaw enough to make him conclude that the muriatic acid, in the ſtate of a yellow vapour, is deprived of a part at leaſt of the phlogiſton which he ſuppoſed it to contain when in its ordinary ſtate. He alſo found reaſon to conclude that it has a ſtrong diſpoſition to reunite itſelf to that principle; and in conſequence of this attraction, it acts on bodies which contain it,—and this with great vivacity, when they hold it in abundance, and but looſely combined. He accounts in the ſame way for its action on the metals, by which it is eminently diſtinguiſhed from the common muriatic acid, which, as I have told you, acts on them in a languid manner, if in their metallic form, though it diſſolves theſe calces very readily,—more readily indeed than the other acids.

Induced by all theſe facts, Mr. Scheele called this vapour or gas the *dephlogiſticated muriatic acid.* We need not wonder that he employed this language, and viewed the phenomena in this light; for, when he made and publiſhed this examination of manganeſe, the phlogiſton was every where admitted as a principle in chemiſtry, and Dr. Scheele was the very firſt that expreſſed any diſſatisfaction with the ſimple form in which this doctrine was delivered by Dr. Stahl. I have already had occaſion to mention the ingenious and fanciful modifications of the original doctrine of Stahl, which this excellent chemiſt attempted to eſtabliſh, but which he would have been the firſt to abandon, had he puſhed ſome of his own experiments one ſtep farther. I hold it, therefore, to be unpardonable arrogance in the French chemiſts to ſay that no man can entertain the belief of the exiſtence of phlogiſton who has a grain of common ſenſe. Scheele's diſſertations, of every kind, will ever ſtand in the very firſt rank of chemical writings. By the natural progreſs of all knowledge that is founded on

experiment, we have come to interpret the many diſcoveries of Dr. Scheele in a different way; but the diſcoveries remain the ſame, and they are his, and reſulted from deep and ingenious meditation. He conſidered all the phenomena which we derive from the privation or abſence of oxygen as proceeding from the addition or preſence of phlogiſton; and he aſcribed to the abſtraction of phlogiſton what we know to be owing to the acquiſition of oxygen.

Since the time of Dr. Scheele, all theſe phenomena of the muriatic acid and manganeſe have been maturely conſidered, and carefully inveſtigated, and clearly explained, principally by the chemiſts of France. We now hold that the change of appearance and properties which the muriatic acid ſuffers depends on the addition to it of a great quantity of oxygen, which it acquires from the manganeſe. For this reaſon, the muriatic vapour which I am now conſidering has got the name of OXYGENATED MURIATIC ACID. Mr. Kirwan calls it the OXY-MURIATIC ACID. You certainly recollect that I have ſeveral times had occaſion to mention a particular ſtate of this acid, in which it was ſurcharged with oxygen; and in conſequence of this redundancy, had ſome ſingular properties. It was thus that I explained the proceſs for preparing muriatic æther by means of the ſmoking liquor of Libavius, and ſeveral experiments of Berthollet, eſtabliſhing the conſtitution of volatile alkali, with other things of ſimilar nature. It was this preparation which I then had in my thoughts.

We have proof that the acid, in Dr. Scheele's experiment of diſtilling it from manganeſe, has abſtracted oxygen from that mineral. Filtrate what remains in the retort, and add a very pure fixed alkali,—the manganeſe is precipitated in the form of a white powder or mud; a ſure ſign of its having loſt ſome of its oxygen. If the precipitate be haſtily waſhed and dried, and then urged by a ſtrong heat, in a proper apparatus, we may perhaps ſtill obtain ſome oxygen, by the extreme force of heat, but the quantity will be exceedingly ſmall.

I may now repeat, in a more comprehenſible and inſtructive man-

ner, what I formerly mentioned when I gave you an example of the manner in which the French chemiſts extended the doctrine of La voiſier to almoſt every chemical phenomenon in this world, namely, their account of the conſtitution and formation of the volatile alkali. When the pure or cauſtic alkaline gas is made to mix with the oxy-muriatic gas, there is an immediate decompoſition of both. The redundant oxygen of the latter ſeizes on the hydrogen of the volatile alkali, and forms water; and the azotic gas is ſet at liberty; and the oxy-muriatic gas is changed into common muriatic acid, by the departure of the redundant oxygen. If we have made uſe of a watery ſolution of the cauſtic volatile alkali, and make the oxy-muriatic gas paſs through it, we have an effervescence, occaſioned by the extrication of the azotic gas. All this was diſcovered by Dr. Scheele, and is related in his Eſſays.

Some of the French chemiſts, and particularly Mr. Berthollet, the moſt eminent of them, have followed Mr. Scheele in the inveſtigation of the properties of this remarkable gas, and have made ſome very curious and important diſcoveries relating to it.

I ſhall briefly mention ſome of its leading properties, referring you for farther information to Mr. Berthollet's moſt excellent diſſertation *Obſervations ſur quelques combinaiſons de l'Acide Marin dephlogiſtiqué, ou de l'acide muriatique oxygéné, par Mr. Berthollet.* It is one of the beſt pieces of experimental philoſophy that has appeared in any language.

1. The oxy-muriatic gas retains its affinity for alkalis, but wonderfully diminiſhed, and modified by very particular circumſtances. It unites, he ſays, with mild alkalis without effervescence. I have not yet examined this with ſufficient care, but am diſpoſed to doubt it. It is ſcarcely poſſible to procure an alkali perfectly ſaturated with carbonic acid. I never ſaw potaſh that was ſo but once. This gas contains ſo little ſaline matter, and its attraction is ſo weak, that it muſt of neceſſity attach itſelf in preference to ſuch of the alkali as is in a

cauſtic ſtate; and I apprehend that this may have been enough to abſorb the whole. The vaſt quantity of water alſo, that is neceſſary for condenſing the gas, may abſorb a great part of the carbonic acid that is really detached from the alkali; and the fact is, that heat applied to this mixture will detach much carbonic acid from it.

2. When the oxy-muriatic gas is condenſed by a very diluted ſolution of cauſtic potaſh, the alkali became turbid, and depoſited ſome earth, and ſome ſaline cryſtals. The mixture being evaporated by a moſt gentle ſand heat, afforded two ſalts,—namely, the ordinary ſalt of Sylvius, and another, eaſily ſeparable from that ſalt, becauſe it diſſolves much more copiouſly in hot than in cold water. When the proceſs is well performed, we obtain about four parts of ſalt of Sylvius and one of this new ſalt.

3. This ſalt has many ſingular properties. Its cryſtals are hexaedral priſms, or more frequently confuſed laminæ. It has an unpleaſant maukiſh taſte, and raiſes a feeling of coolneſs on the tongue, as nitre does. It contains the acid in its highly oxygenated ſtate. An hundred grains of the dry ſalt yield 75 cubic inches of vital air by means of heat, and yield it more eaſily than nitre does. Mr. Berthollet, obſerving the vital air ſo copious in it, and ſo looſely combined, mixed it with charcoal, and tried whether this would detach it by the aſſiſtance of heat. It deflagrated with prodigious violence, and the acid was not deſtroyed, but only reduced to its ordinary form; for the reſiduum was the ordinary ſalt of Sylvius. Therefore no oxygen had operated in this detonation, except the portion obtained from the manganeſe. Mr. Lavoiſier found that 100 grains of the ſalt contains 37 of oxygen, which requires 14 of carbon to ſeparate it, and produces 51 cubic inches of carbonic acid.

4. Mr. Berthollet, from theſe and other analogous experiments, infers that all the oxygen which produced that change in the marine acid is concentrated in this ſalt, and that it contains no other, nor any acid in its ordinary ſtate. He therefore calls it the OXYGENATED MURIAT

of potaſh or of ſoda. One part of this ſalt contains all the redundant oxygen that is furniſhed by ſix of oxy-muriatic acid. I may remark that the nitroſe acid, in its union with alkali, exhibits phenomena pretty ſimilar. We obtain a true nitre, and a nitrous gas.

The union of the ingredients of this oxy-muriat ſeems very ſlight. Expoſition to the air ſeems to decompoſe the acid: For in a few days, or even hours, the ſalt changes to the ordinary ſalt of Sylvius. This decompoſition happens more ſpeedily in a watery ſolution of the ſalt; and we ſee a continual ſimmering on its ſurface, by the eſcape of minute bubbles of elaſtic matter. This is increaſed by expoſure to the rays of the ſun ſo as to be like an effervescence. This is vital air, of the pureſt kind. It would ſeem that the cauſtic alkali acts too powerfully on the baſis of the ordinary muriatic acid, and thus diminiſhes its attraction for the oxygen; or the oxygen exiſts in it, perhaps, in a ſemi-elaſtic ſtate. Mr. Berthollet alſo thinks that the vaſt abundance of water neceſſary for abſorbing this gas prevents a cloſer union of the acid and alkali. He found that the combination could not be effected unleſs the ſolution of the alkaline ſalt be extremely diluted. If this liquor be evaporated, preſerving it at the ſame time from the action of light, or the naked fire, it undergoes, at a particular period of the evaporation, a ſudden change, by which the above ſalt is formed; and that after this, neither the liquor, nor any of the ſalts which it affords by evaporation, are poſſeſſed of the peculiar powers of the oxy-muriats.

Mr. Scheele diſcovered in this oxygenated acid another moſt remarkable property, namely, a power to deſtroy all vegetable and animal colours, and even thoſe which are moſt permanent, prepared for the purpoſes of dying. It whitened or bleached vegetable ſubſtances in a ſurpriſing manner. Mr. Berthollet firſt thought of applying it to this uſe, and found that bees wax, brown linen yarn, and cloth, are bleached by it in a few hours or minutes, as effectually, and with as much ſafety to the ſtaple of the goods, as if they had been expoſed to the ſun and air, with that intention, for as many weeks.

In conſequence of this great diſcovery, trials have been made, with a view to the employing it in the art of bleaching fine linen, or cotton cloths, threads, and light manufactured goods. Mr. Berthollet has publiſhed the proceſs, as it has been practiſed in ſome manufactories in France; and his account of it is tranſlated into our language *.

The firſt trial of it in the great way, however, was (according to the beſt of my information) made in Scotland, with the aſſiſtance, and under the direction of Mr. Watt, who had been at Paris, and had converſed with Mr. Berthollet, and immediately formed the deſign to try if the powers of this acid could be employed in practice; for Mr. Berthollet had only conſidered it as a project in ſpeculation. Mr. Watt had an opportunity ſoon after to make his experiments in the bleachfield of a friend at Glaſgow; and ſince that time, the proceſs has been applied to this purpoſe in many other bleachfields. It is beſt adapted, however, to the bleaching of thin goods, ſuch as lawns, and fine muſlins, and fine thread, and ſtockings. Theſe require leſs of the acid than coarſer goods, the thick and harſh threads and fibres of which are penetrated with difficulty, and alſo contain much colouring matter,

* Therefore I need only mention here, that Mr. Berthollet produces the oxygenated vapour of muriatic acid, or oxygenates the acid, during its formation. He mixes, in dry powder, ſix ounces of black manganeſe with 16 of common ſalt. A tubulated diſtilling veſſel is prepared, whoſe pipe is inſerted into a receiver with two necks, and into the oppoſite neck is inſerted the pipe which conveys the gas into the veſſel containing the liquor which is to abſorb it, or the matters which are to be bleached by it. This powder is put into the retort, and then there is poured on it 12 ounces of ſtrong ſulphuric acid, diluted with nearly as much water; and the ſtopper is put in. Gas is immediately produced in vaſt abundance, and paſſes into the reſt of the apparatus. The two-necked receiver condenſes the ordinary muriatic acid; but the oxygenated gas paſſes on to the abſorbing veſſel. No heat is applied till the emiſſion of vapour becomes very gentle. The heat is cautiouſly and ſlowly raiſed to boiling, and continued till the two-necked receiver grows hot. This finiſhes the diſtillation. The abſorption is promoted by churning vanes, which are worked by ſome machinery. Thus the abſorbing liquor is more ſpeedily and thoroughly impregnated. (*Annales de Chymie, t.* ii.)

which ſoon exhauſts the ſtrength of the gas. Attempts have alſo been made to bleach rags for paper. The methods employed are frequently to wet the matter to be bleached, by dipping it into water, while it is at the ſame time expoſed to the vapour of the acid; or water which has been made to abſorb ſome of the vapour is applied to it; or it is ſteeped in a ſolution of fixed alkali, or in lime-water, which has abſorbed ſome of the vapour. Such ſolutions are found to have the bleaching power, although the acid be ſaturated with alkali.

Different methods are employed by different manufacturers, according to their notions of their reſpective efficacy; and each manufacturer has his noſtrum, which is a ſecret. At preſent, none of them, I believe, uſe the ſimple oxygenated acid, which was formerly prepared for them, as a ſteep. The ſmell which it occaſions is abominable, and cannot be cleared from the hands for many days. The workmen therefore will not ſubmit to it. They either uſe the vapour procured by Berthollet's proceſs, with alternate dippings into water,—the whole of which operation is performed in a cloſe chamber by the intervention of machinery; or, more commonly, they employ ſolutions of alkali impregnated with the vapour. A chemiſt in Glaſgow has made a great improvement upon the whole proceſs, by employing lime inſtead of alkali. He thereby prepares the drug in a very concentrated, and even a ſolid ſtate.

Mr. Berthollet's trials to combine this volatile acid with fixed alkali have alſo produced ſome other ſurpriſing diſcoveries. Obſerving how much the oxyd itſelf was diſpoſed to give out its oxygen to inflammable ſubſtances, and how looſely it is combined in the acid overcharged with it, while this acid ſtill retains its relation to alkalis, he tried the effect of the neutral ſalts produced by it. When the oxygenated muriat of potaſh is ground in a mortar with ſulphur, ſmall exploſions happen under the peſtle, which affect the hand of the operator like an electric ſhock; and if haſtily ground, with ſtrong preſſure,

the whole will explode. Nay, if the ſalt alone be thrown into ſulphurous acid it will explode.

Mr. Berthollet alſo examined, in the ſame way, the ſuper-oxygenated muriat of ſoda. This deliqueſcent neutral ſalt gives out its abundant oxygen by mere expoſition to the air, and changes to common ſea ſalt. When treated in cloſe veſſels, 100 grains yielded 75 cubic inches of vital air, of the greateſt purity, with much leſs heat than nitre yields it. It was now a common muriat of ſoda.

He compoſed a gunpowder with the muriat of potaſh; and it was ſaid to be vaſtly ſtronger than the nitrous gunpowder. Trials were made of it at Woolwich; and it was found that it was really ſtronger in ſmall charges,—but there was no ſenſible difference in great quantities, ſo that it was not thought worth while to proſecute the diſcovery further *.

Such gunpowder has qualities which make it inferior to the common. The very looſe combination of this oxygen muſt cauſe the powder to become effete. The reſiduum of the detonation will be digeſtive ſalt, inſtead of the hepar ſulphuris left by the ordinary powder. This will be more hurtful to the fire arms than fixed alkali. It would alſo appear, from the accident which happened in the preparation, that it is more diſpoſed to explode in the operation of grinding.

From the whole of what I have ſaid on this ſubject, it appears that the nature of the muriatic acid is very ſingular, when we compare it with the other two foſſil acids.—Theſe, when they have not the ſufficient quantity of oxygen, are more volatile than ordinary, and their attraction for water is diminiſhed. The muriatic acid, on the contrary, has its volatility increaſed, and its attraction for water diminiſhed, by receiving enough of oxygen.

Mr. Scheele's experiments and reaſonings have alſo ſhewn that

* The oxy-muriats of lime, barytes, and ſtrontites, deſerve a trial for a fulminating compoſition. EDITOR.

there is a ſingularity in manganeſe, when we conſider it as a metallic calx. It is moſt coloured, or darkeſt, when moſt calcined, and becomes white by abſtraction of oxygen, contrary to other metallic calces. And it gives colour to its ſolutions, and to glaſs, when it is highly oxydated; but when this high degree of oxydation is abated, the colour diſappears. The oxyds of other metals in general give moſt colour when they are leaſt oxydated. This ſingularity in manganeſe is finely ſeen by treating a ſmall portion of it with the blowpipe. A ſmall bit of the ſal microcoſmicus being melted on charcoal by the blowpipe, if a minute portion of the black manganeſe be added, the globule acquires a red colour, ſo much the fuller, as we have added more of this oxyd. If we keep this globule in the middle or blue part of the flame, where it is defended from the action of the air, the red colour vaniſhes, by the reduction of the calx by the charcoal. If we now direct the point or exterior part of the flame to the under ſide of the globule, the effect of the charcoal is prevented, and the reduction already operated is deſtroyed, and the globule becomes red. We may thus change the colour as often as we pleaſe. The ſmalleſt particle of nitre being put to the colourleſs globule makes it red in an inſtant, by calcining the manganeſe.

A globule of manganeſe and borax preſerves its dark red or black colour under this treatment, probably by keeping it from touching the charcoal.

We have an example of the colour it gives in its highly oxydated ſtate, in a watery ſolution of a compound of manganeſe and fixed alkali, analogous to a *liquor ſilicum*. This combination is beſt formed by mixing the manganeſe with nitre, and giving the mixture a mild melting heat. The nitric acid is expelled by the heat, leaving the manganeſe well ſtored with oxygen. The alkali remains combined with the manganeſe, and forms with it a dark green or blackiſh maſs, which is ſoluble in water,—and gives it a green colour. We ſhould perhaps account it a blue, becauſe in a day or two a yellow powder falls down,

and the ſolution is blue. The combination is but looſe. Water ſeparates it, firſt of a violet colour,—then red, which grows brown,—and laſtly black. If ſulphuric acid be added to ſeparate the alkali, the ſolution becomes colourleſs, the acid diſſolving the deoxygenated manganeſe. Such a variety of colours have procured to this ſolution of nitre alkalized by manganeſe the name of *chamelion minerale*.

If we add a few drops of a ſolution of hepar ſulphuris to the ſolution of manganeſe in the fixed alkali, it no longer exhibits the changes of colour. It produces this effect by its ſtrong attraction for oxygen, by which it deprives the manganeſe of that preciſe quantity which enabled it to impart thoſe colours.

It would appear that manganeſe clears glaſſes of the yellow and green colours which tinge them, by yielding a quantity of oxygen ſufficient for calcining the colouring matters. When too much manganeſe is employed, after having diſcharged the colours produced by other metallic contaminations, it communicates its own colour,—a purple *.

Liquid phoſphoric acid, as produced by the ſpontaneous decompoſition of phoſphorus without heat, diſſolves manganeſe, giving a fluid of a rich red colour. If this be kept in a phial cloſely ſhut up, it loſes its colour,—but reſumes it by expoſing the whole to the air in the proceſs of filtration. This may be repeated as often as we pleaſe, and no matter is ſeparated by the filtration. This is undoubtedly pro-

* This property ſeems to me to have been longer known than is commonly ſuppoſed. Pliny ſays, " Mox, ut eſt aſtuta et ingenioſa ſolertia, non fuit contenta nitrum miſcuiſſe. " Cœptus addi et *magnes lapis*: quoniam in ſe *liquorem* vitri quoque ut Ferrum trahere " creditus." I think it probable that *magnes lapis* is manganeſe. The ſentence has no truth, if the loadſtone be meant, for this deſtroys all beauty in glaſs. Foſſils were then little known, and Pliny was not a ſkilful foſſiliſt,—*liquorem* may be a corruption for *colorem* or *livorem*. He is ſpeaking of the perfection to which the manufacture had been brought, and ſays that the moſt valued was what is clear and colourleſs as cryſtal, and then he relates the above practice.

duced by abſtraction of oxygen from the manganeſe, and reſtoration of it by the atmoſphere.

Acetous acid diſſolves the black oxyd, and, in this ſtate, very readily produces æther, when treated with alcohol. It alſo gives moſt beautiful cryſtals, when employed to diſſolve copper.

Mr. Milner of Oxford publiſhed a paper in the 79th volume of the Philoſophical Tranſactions, giving the general reſult of a number of experiments he had made with manganeſe, by making it red hot, in tubes of iron, or of earthen ware, and forcing the ſteam of water and of other things to paſs over it, or through it; and among theſe, he tried the vapours of the pure or cauſtic volatile alkali. It always happened, that when the vapour of this alkali paſſed through the red hot manganeſe, it was partly converted into vapour of nitrous acid. This effect was conſtant; but he did not attempt to examine and aſcertain how much of the nitrous acid might be produced from a limited and known quantity of the volatile alkali.

This remarkable and intereſting experiment is eaſily explained by Mr. Cavendiſh's diſcoveries, and the new theories in chemiſtry to which they have given riſe. He diſcovered that water is produced from inflammable air and vital air; and that nitrous acid can be produced from azotic gas (phlogiſticated air) and vital air. Therefore, to underſtand Mr. Milner's experiments, ſince we know that the volatile alkali is a compound of hydrogen and azote, we need only to ſuppoſe that part of it is totally decompoſed and deſtroyed by the action of the oxygen contained in the manganeſe. Part of it, uniting with the hydrogen, forms water or watery vapour; and part, uniting with the azote, forms vapours of nitrous acid.

He obſerved alſo that the ſteam of water, paſſing through red hot manganeſe, promoted very much the extrication of thoſe gaſes which it affords by heat *.

* *January* 1796. There is a rumour that the French have manufactured ſaltpetre, during a part of the war, by obtaining nitrous acid from the vapours of volatile alkali, forced to paſs through red hot manganeſe. AUTHOR.

Having mentioned the moſt important properties of this remarkable ſubſtance, we ſhould next conſider the methods of reducing it to its metallic ſtate. This has been but little ſtudied; and its metallic properties are very imperfectly known. The reduction of manganeſe to a regulus is a very difficult proceſs. This was firſt accompliſhed by Mr. Gahn of Sweden.

A crucible muſt be lined with wetted charcoal, (rendered very denſe, and compacted by beating), leaving a ſmall hollow in the centre, to receive a ball of the oxyd, made up with oil into a compact paſte. Charcoal is put in above it, and well compacted by beating, and another crucible is luted on, alſo filled with charcoal. The moſt violent heat muſt be given for an hour and an half. A button is thus procured, of a dull iron colour, commonly rough on the ſurface. This ariſes from minute globules of manganeſe leſs perfectly reduced. It requires even more heat than iron for its fuſion; and no chemiſt has been able to join pieces in this way. All ſaline fluxes are found hurtful to the operation.

The metal quickly calcines by expoſure to the air, and is ſoon reſolved into a black oxyd. To preſerve ſpecimens in a metallic ſtate, it is neceſſary to varniſh them; for even the air of a phial ſuffices for ruſting it in a few hours. I have ſome ſuſpicion that it abſorbs azote as well as oxygen, for I obſerve that it leaves a ſmaller portion of that gas unabſorbed than any other proceſs I have tried. 200 grains of regulus increaſed in weight 76 grains in the open air. Another 200, from the ſame maſs, expoſed in vital air, increaſed only 65 *. The ſpecific gravity of magneſium is about 6,35. It is quite brittle; and uſually contains iron, which is not ſeparated without extreme trouble.

* This conjecture of Dr. Black's is corroborated by the obſervation of Mr. Seguin, that black manganeſe yields azotic gas in low heats. EDITOR.

GENUS III.—IRON.

After magnaneſe, we are now to conſider iron.

I chooſe to deſcribe iron next, and among the firſt of the metals, for many reaſons. It is the moſt abundantly produced by nature. It is alſo by far the moſt uſeful among the metals, and of the greateſt importance, by having a combination of properties, which make it an excellent ſubject for the ingenuity and induſtry of man to work on. Theſe properties are, a ſtrong coheſion of its parts, by which it excels all the other metals; and which, in ſome ſtates of the iron, is attended with great toughneſs and ductility; in others, with exceſſive hardneſs; and in others, with great elaſticity *. In theſe different ſtates, or intermediate ones, it is excellently adapted to different uſes. We can alſo ſoften it by heat, and thus work it eaſily, under the hammer, or by the compreſſion of rollers, into different forms; and when ſtrongly heated, different pieces of it can be joined firmly together. We can alſo have it in a fuſible ſtate, and caſt it in moulds.

Iron is ſingular among the metals, and indeed all other bodies in nature, by being the only one affected by the magnet; and as the magnet can be made to communicate to iron its own polarity, and other magnetic qualities, this metal becomes thereby ſtill the more uſeful. Artificial magnets can be made of it, far exceeding the natural ones in ſtrength. A very ſmall magnet, turning freely on a point, is the needle of the mariners compaſs, and pilots our ſhips through the trackleſs ocean.

While iron is cold, though it be tough and flexible, it is too hard and ſtrong to be workable under the hammer, as ſome metals are; and, beſides, it ſoon loſes its toughneſs when we hammer it ſtrongly,

* An iron wire, of one-tenth of an inch in diameter, will carry 450 pounds. A copper wire not quite 300. AUTHOR.

its latent heat being thus eaſily driven out of it. It retains its latent heat and toughneſs much better while it is drawn into wire, and it can therefore be drawn into very fine wire. Its coheſion is greatly increaſed by this operation. When it is red hot, it is very malleable, and almoſt plaſtic like clay, and can be beaten by hammers, or compreſſed by rollers into very thin plates.

It is one of the moſt refractory metals, when in its pureſt ſtate. The moſt intenſe fires can hardly melt it, when it is expoſed ſimply to the action of heat in cloſe crucibles. In its unrefined ſtate, it can be melted eaſily, and perfectly, by a violent heat, in the temperature 17,977° Fahrenheit, or 130° Wedgewood; and the contact of the fuel increaſes its fuſibility. Mr. Lewis ſays that gypſum has the ſame effect.

When pure or tough iron is heated to a white heat, 90° of Wedgewood, different pieces of it can be made to cohere and unite perfectly into one piece by hammering them into cloſe contact. This is a common operation of the blackſmiths: They call it *welding*. Some ſand, or pounded ſand-ſtone, is thrown into the fire in performing this operation. The ſand melts on the ſurface of the heated iron, by uniting with a little of the metal that is calcined, and forms a liquid glazing, which defends the metal from farther calcination, and keeps the ſurface of the different pieces in a condition for uniting together, when they are properly applied to one another. Sand is of the ſame uſe here as borax is in ſoldering. This liquid glazing readily flies away from between the pieces, when they are hammered into contact.

The only defects of this metal are thoſe of being too eaſily calcinable, and too liable to the action of different ſolvents. It is capable of being calcined ſo ſuddenly and violently, as to give all the appearances of inflammation: As,

1*ſt*, When heated to a white and dazzling heat, and ſuddenly expoſed to a ſtream or blaſt of air, brilliant ſparks are darted from it,

which the metallurgiſts call *brandiſhing*. Theſe are ſigns of the iron being inflamed, and calcining rapidly.

2*dly*, The fiery ſparks produced by the colliſion of flint and ſteel are another example of it. They are ſmall parts or rags of the ſteel, torn off by the flint. By the violence with which they are ſeparated from the maſs, and the extrication of latent heat, they are heated red hot; and in falling through the air, are blown up into an inflamed ſtate. That it is not a ſimple ignition or incandeſcence, occaſioned by the great heat generated by friction, is evident from this, that if the ſame experiment be made in fixed air, they are then ſeen juſt like ſo many ignited particles of ſand, and the light is ſeen only in the very ſpot where the colliſion is made; whereas the ſame ſparks in free air are brighteſt when they have got to ſome diſtance, and ſeem to brighten by degrees as they recede from the ſtroke. Sometimes a brilliant ſpark is not ſeen at all, till at a conſiderable diſtance; and it branches and ſplits into two or three ſparks. Alſo, when the two ſets of particles are examined with a microſcope, thoſe that were driven off into fixed air are plainly thin rags of metal, which have been ſcraped off by the flint, and rolled up into a ſort of ſpiral; whereas thoſe ſtruck off into good air are ſcorified and bliſtered, and can be cruſhed to powder between the fingers. Nay, if a fine ſteel wire be twiſted round a thick one, and if the whole be thruſt red hot into a veſſel containing vital air, the fine wire will take fire, and burn away like a ſquib, crackling and brandiſhing with great brilliancy.

3*dly*, Similar ſparks are produced by throwing fine iron filings through the flame of a candle.

4*thly*, Larger maſſes of iron are eaſily made to burn in the ſame manner, by heating them in vital air, or introducing them red hot into it. It is this violent inflammation that makes the ſpark of iron ſtruck off by flint kindle gunpowder with ſuch abſolute certainty. Were it merely red hot when ſtruck off, it would be ſo much cooled in its paſſage, that it would produce no ſuch effect. Other metals,

equally or perhaps more inflammable, will not do, being too ſoft for producing the firſt heat by the ſtroke.

Iron expoſed to a mild heat gradually increaſed, is calcined at the ſurface, without producing any heat or light. The firſt phenomenon of this calcination of a bit of poliſhed iron, is the appearance of rainbow colours on its ſurface, before the iron is red hot, but juſt approaching to that heat. The ſucceſſion of colours is faint yellow, golden colour, purple, violet, and deep blue, weakened inſenſibly to a water colour, which is the laſt ſhade diſtinguiſhable before it is red hot. After this, a duſky cruſt and friable ſcales appear. When long calcined, the colour is deep red. All the calces of iron, if much calcined, are either duſky yellow, red, or purpliſh. Hence they are called *croci*.

This ſucceſſion of colours admits of a very ſatisfactory explanation, by the diſcoveries of Sir Iſaac Newton concerning the colours produced by tranſparent thin plates. The colours ſucceed each other in that order in which they ſhould follow, were they produced by a tranſparent plate, gradually increaſing in thickneſs. Now we know that this ſucceſſion of colours terminates in the production of a ſcale of calcined or oxydated iron. We alſo know that the calces of metals are frequently tranſparent coloured glaſſes, and in all caſes, compoſe ſuch glaſſes by admixture with earths.

When iron is thus calcined, the power of the magnet over it diminiſhes; and when the calcination is carried to a certain length, becomes imperceptible. The ſcales are ſtill attracted, but much more weakly than iron; and if further calcined, there is no more ſenſible attraction. Nor is the ruſt, formed by long expoſition to the air, or any of the natural calces or ochres of a yellowiſh or reddiſh colour, attracted ſenſibly, in the common way of making the experiment. They are eaſily brought back again, however, to a leſs calcined, or leſs oxydated ſtate, ſo as to recover the black or duſky colour of the ſcales, and then they are attracted by the magnet. We need only to

mix them with a little charcoal duſt, or any animal or vegetable matter, and make them red hot.

Iron is not only diſſolved by ſeveral acids, but it is acted upon by all the ſaline ſubſtances without exception. They either corrode the metal, or diſſolve the ruſt or calx. Water alone, or moiſt air, has conſiderable effect, and is perhaps the chief agent in all theſe corroſions. It has, therefore, long been a deſideratum to preſerve the ſurface of poliſhed iron from corroſion by the air and weather, *i. e.* from ruſting. The only method is to cut off the communication by ſome varniſh. Oily or greaſy matters are the fitteſt, eſpecially ſuch as harden in the air. Pure lintſeed oil, or hempſeed oil, are therefore preferable, when ſpread over the iron, by rubbing it with a clean flannel cloth dipped in the oil, and rubbed on ſo as to leave no ſenſible quantity. The very operation of poliſhing has a conſiderable effect, for it is always by the means of cutting powders, rubbed on with greaſe of ſome kind or other. The blue colour produced by heating the iron is alſo thought to defend it.

All the acids act on iron, and diſſolve it. Even the carbonic acid, eſpecially if aſſiſted by water, diſſolves it. For this reaſon, it is uſual, in the manufactories of poliſhed goods, to throw them into lime-water, or water having lime in it, to preſerve them from ruſting during the time that they are in the hands of the workmen. The ſulphuric acid diſſolves the iron the moſt readily and completely. But it muſt not be applied in its ſtrongeſt ſtate. It is neceſſary that a good deal of water be added at the ſame time. I had an opportunity not long ago to ſhew you how the iron is diſſolved by ſulphuric acid thus diluted, and the great quantity of inflammable air which is produced during the diſſolution. The production of this inflammable air is undoubtedly beſt explained by the new theory of the French chemiſts. It proceeds from the water, which the iron decompoſes.

The proofs of this are, 1*ſt*, When we force the ſtrong ſulphuric acid to act on iron filings, without adding water, but ſimply by heat,

we do not get inflammable air,—we obtain ſulphurous acid. And the acid, deprived of part of its oxygen, becomes ſulphurous acid, which does not act readily on iron. This action requires a very great heat; and when the mixture is diſtilled to dryneſs, we obtain a ſublimate of ſulphur, deprived of all the oxygen with which it formed the acid. The ſolution of the iron, therefore, required more oxygen than was ſupplied by that part of the acid which really diſſolved it, and combined with it. Even this ruddy compound of acid and iron is not completely neutralized, it being a very deliqueſcent ſalt, whereas the green coloured ſalt, produced from a diluted acid, even falls to powder by evaporation.

2*dly*, Water alone can be made to act on iron, ſo as to produce inflammable air in great abundance. Even in the ordinary heat of the atmoſphere, it produces ſome inflammable air, and changes the iron into a ruſt or calx. Iron filings, digeſted in pure water, are converted into calx, and a quantity of inflammable air is produced. Red hot iron, plunged into water, cauſes a thick black ſcale to form inſtantly on the iron, and much inflammable air is diſengaged. This ſcale is ſimilar to that which forms on iron ſimply heated in the air. This, I believe, ſuggeſted to Dr. Prieſtley a much more effectual way of applying the water, namely, in the form of ſteam, when the iron itſelf was red hot. It was ſent through a porcelain or copper tube, in which iron wire is coiled up, and it converted the whole into the ſame calx; and inflammable air was diſengaged. Water conſiſts of oxygen and hydrogen, the baſis of inflammable air. It appears, therefore, that the calx is produced by the decompoſition of the water, which oxydates the iron, while the inflammable air eſcapes.

When the diluted acid acts on iron, as the ſolution goes on, a double operation ſeems to be going forward. There is a copious formation of a black mud, which is of the ſame nature (at leaſt a great part of it) with the oxyd formed by iron and water. This ſeems to

be a different proceſs from the ſaturation of the acid: For, if the acid has been but little diluted, the ſolution ſtops, but is renewed by adding more water. The water of the acid is employed in forming the martial ſalt; and now the acid has not enough to continue this formation, till freſh water be added. But the mud is an oxyd deriving its oxygen from the water only.

When the ſulphuric acid is ſaturated with iron, and the effervescence ceaſes, the ſolution is muddy for ſome time, but at laſt becomes clear, and of a light green colour. The matter which made it muddy is obſerved partly at the bottom, and partly at the top. It is of a blackiſh colour, and reſembles the duſt of what is called *black lead*, or *plumbago*. Profeſſor Bergmann analyſed this blackiſh ſediment, and found that it has really the qualities of plumbago, which had been analyſed before by Mr. Scheele. It is compoſed of carbon, united to a ſmall quantity of iron. If we take either black lead of the fineſt kind, or the black matter now ſpoken of, and expoſe it to the moſt intenſe heat in cloſe veſſels, it ſuffers little or no change. But in open air, it is all conſumed, except an ochry calx, variable in quantity.—But much of it eſcapes, by being volatilized without change. It detonates with nitre, requiring a very great proportion of nitre to finiſh the detonation entirely. We obtain carbonic acid by this proceſs; and the nitre, beſides being alkalized, contains ſome ochre, and is greatly diminiſhed in quantity. It would ſeem that theſe things happen, becauſe this combination of carbon requires a heat for its combuſtion ſo much greater than charcoal does, that the nitre muſt be raiſed to ſo high a temperature that much of it is diſſipated in vapour. Plumbago may therefore be conſidered as a ſpecies of charcoal, which has a ſmall quantity of iron for its baſis, inſtead of the ſmall portion of earth and ſalt contained in common charcoal.

To free the ſolution of iron from this black matter, it muſt be filtrated, and then evaporated. It gives green cryſtals, called *green*

vitriol, or *ſal martis*. Great quantities of it are uſed in ſome of the arts by the name of *copperas*; but it is made by a much cheaper proceſs. Theſe cryſtals contain much water. They undergo the watery fuſion and ſpontaneous calcination. The matter which remains, after the water is evaporated from them, is called *calcined vitriol*; and, according to the degree of heat employed, vitriol is calcined to whiteneſs,—to light red,—to redneſs,—and laſtly, we have *colcothar* of vitriol. The heat applied enables the iron to act powerfully on the acid, and to attract from it a part of its oxygen. Hence the metal becomes highly oxydated, and in that highly oxydated ſtate it has a deep red colour. From this compound the vitriolic acid was formerly obtained; whence its name. And it is ſtill uſed in ſome proceſſes, in which the action of the vitriolic acid is neceſſary, as in the old proceſs for aquafortis.

I preſume that you now ſee the propriety of conſidering vitriol, and other metallic ſalts, formed by an union with acids, as ſalts of a ſecondary order of compoſition; one of their ingredients, namely, the acid, being avowedly a compound of oxygen and another baſe. Hence ariſes the difference of the ſalts formed of the ſame metal and different acids. We muſt therefore conſider vitriol and colcothar as very different from the black *æthiops martialis*, from which the carbonic acid has been expelled. This is a compound of iron and oxygen, but colcothar is a compound of iron, and oxygen, and ſulphur *.

The nitric acid, the next in order, is ſeldom applied to the metals in its ſtrongeſt ſtate. In that ſtate, it contains too little water to diſſolve the compounds which it forms with the metals. In diſſolv-

* There is here ſome difference of opinion among the chemiſts, or at leaſt in the way of conceiving this circumſtance. By proper treatment, all the acid may be expelled from the green vitriol by heat, and the iron is left combined with about one-half its weight of pure oxygen. The name of *colcothar* is given alſo to this oxyd by ſeveral eminent chemiſts; while others conſider colcothar as this very oxyd, with this doſe of oxygen, but farther combined with a ſmall portion of ſulphuric acid. They

ing metals with it, we commonly employ it diluted with an equal quantity of water, and in this diluted ſtate it is called *aqua-fortis.*

If we attempt to diſſolve iron filings in aquafortis, in the ſame manner as when we diſſolve them in diluted ſulphuric or muriatic acid, the action of the materials is rapid, the mixture becomes hot in a moment, and there is an outrageous effervescence, or a ſort of exploſion. The acid is changed into elaſtic red vapours and incondenſible gaſes. The iron attracts the oxygen of the acid with too much violence, and in too great quantity. It decompoſes too much of the acid, and is itſelf oxydated to ſo high a degree, that it requires a very large quantity of the acid for its diſſolution. The acid employed is, therefore, not ſufficient for diſſolving it, and the iron is only corroded.

To diſſolve iron well in this acid, we muſt moderate the action of the metal and acid on one another, by preſerving them cool, and adding the iron very gradually, and with much leſs ſurface for the acid to act on. In this way, an ounce of aquafortis diſſolves only 26 grains, ſomewhat leſs than one-eighteenth.

There never is any inflammable air produced during this diſſolution of the iron in the acid of nitre, nor in diſſolving any other metal in that acid. The reaſon is plain. The iron, while diſſolving, is diſpoſed to attract a quantity of oxygen, but it eaſily obtains it from the acid. The nitric acid abounds with this principle; and contains it in a more looſe, and ſeparable, and active ſtate, than the ſulphuric or muriatic acids do in their ordinary form. The iron, therefore, gets it

conſider green vitriol as another oxyd, having a much ſmaller doſe of oxygen (about $\frac{27}{100}$) combined with a much larger doſe of ſulphuric acid. They think that iron has only theſe two ſtates of oxydation, and that the apparently different ſtates in which we ſee it, are only mixtures of theſe oxyds. This doctrine or view of the matter is to be found very diſtinctly expreſſed in a diſſertation of Mr. Prouſt on Pruſſian blue. This variety of opinions is very embarraſſing, when we read the explanations given of other phenomena; and a theoriſt may often ſhift his ground in deſcribing the internal procedure. EDITOR.

readily from the acid, and no part of the water ſeems to be decompoſed, nor is any inflammable air produced.

When the iron is diſſolved in this manner, it firſt tinges the aquafortis of a fine green colour, and ſome thin red vapours of the nitrous acid make their appearance. And by afterwards gradually adding a little more iron, the acid becomes ſaturated, and will not diſſolve any more. Then the red vapours gradually diſappear by flying away; and the colour of the ſolution changes to a pale browniſh yellow.

The green colour which appears at firſt is therefore produced by the preſence of the nitroſe acid in the ſolution, ſince the colour diſappears as ſoon as this acid has time to evaporate entirely. You no doubt remember, that the nitrous acid always gives a green or blue tincture to water with which it is diluted, and that when this volatile acid is allowed to evaporate, the colour diſappears.

You will now better underſtand the reaſon of the violent outrageous effervеſcence which happens when, in place of taking this method, we throw a quantity of fine iron filings into the aquafortis. The acid is allowed, in this caſe, to act on a very extenſive ſurface of the iron, and to come into contact with a great quantity of it at the ſame time. It therefore diſſolves a ſmall part of the metal, and corrodes the reſt with the greateſt rapidity, or in a moment of time. But this rapid diſſolution and corroſion is attended with two accidents: 1*mo*, The ſudden change of the nitric acid into the nitrous acid, by abſtraction of its oxygen; and 2*do*, With the extrication of a great quantity of latent heat from the iron. The mixture becomes ſo hot in a moment, that the glaſs is too hot to be touched. This heat gives great elaſticity, and a deep red colour, to the nitrous acid vapour; and thus is produced that ſort of exploſion.

We cannot obtain cryſtals from this ſolution by evaporating it with that intention, but I have got remarkable cryſtals from it by accident, of an amethyſtine colour.

Chemiſts have often obſerved a ſmell of volatile alkali in the decompounding metallic ſalts by fixed alkalis and by lime. It paſſed unheeded, being attributed to impurities in the alkali or lime, which are known to be generally contaminated by a minute portion of volatile alkali.

But, in the decompoſition of a freſh-made nitrat of iron, this ſmell is very remarkable, if the arbitrary circumſtances of the experiment chance to be favourable. Thus, take two drachms of aquafortis, and dilute it with four of water, ſo that the action on the metal may be very moderate. Diſſolve two drachms of clean iron filings in this diluted acid, keeping all as cold as poſſible, and when the ſolution ſeems ended, add three drachms of ſlaked lime. There will be little effervescence during ſolution; and the lime will immediately occaſion a very ſtrong ſmell of volatile alkali. The formation of this gas is ſo copious that we can even make its eſcape viſible. Moiſten the inſide of a tall glaſs (like a beer glaſs, or ſmall cylinder) with oxygenated muriatic acid, and hold this over the mouth of the ſolution glaſs, and it will inſtantly be filled with a white cloud, and the ſal ammoniac will fall down like ſnow.

This is one of the moſt intereſting experiments in chemiſtry,—and eminently inſtructive. There was not an atom of volatile alkali in the materials. It muſt, therefore, be produced by a ſeparation, and a new combination of ſimpler ſubſtances contained in them. We can now gueſs at the hidden proceſs, by what we know of thoſe materials. The filings of iron decompoſe water, by attracting its oxygen, and ſet the hydrogen at liberty. We know alſo, that, by the ſame ſtrong attraction for oxygen, it decompoſes the nitric acid, and ſets its azote at liberty; or, at leaſt, in a ſtate of redundance, as an ingredient of nitrous gas. We do not know of any other ſubſtances being diſengaged from their former combinations in this experiment. It would not, therefore, be unreaſonable, though perhaps a little haſty, to conclude that theſe two ſubſtances have united, and by their union, compoſe

volatile alkali. Dr. Prieſtley, by paſſing the electric ſpark through volatile alkali a great many times, either extricated or produced a vaſt quantity of hydrogenous gas. It is very true that Dr. Auſtin (*Phil. Tranſ.* 1788.) could not combine thoſe gaſes by heat, nor by the electric ſpark, ſo as to produce ammonia: But he could not expect it, ſince the electric ſpark ſeparated them. Scheele found that when metallic oxyds are reduced by ammoniacal gas, a great quantity of azotic gas is *extricated.* His former experiments did not permit him to ſay that it was *produced*, becauſe they had convinced him that it is a primitive ſubſtance. Bergmann, therefore, was diſpoſed to think that volatile alkali conſiſted of the two ſubſtances, azote and hydrogen.

Dr. Auſtin could not combine the gaſes by heat. This is not an objection. Heat combines oxygen and azote in the ſame manner as it promotes all combuſtions. But here is no combuſtion. There are many other examples where the baſes of the elaſtic gaſes combine, although the gaſes themſelves will not, being hindered by their combination with caloric. I take this to be one. The two ſubſtances meet in the very inſtant of their extrication from their former combination. Dr. Auſtin ſucceeded, however, when only one of the ſubſtances was in the gaſeous ſtate. Iron filings, moiſtened with water, were put into a ſmall quantity of azotic gas, confined by mercury. The volatile alkali was produced.

The operation of the quicklime in the experiment which led me into this diſcuſſion is very evident. It prevents the inſtant union of the volatile alkali with ſome of the acid; or it decompoſes the nitrous ammonia as faſt as it is formed. The want of this prevents the appearance of the volatile alkali in every ſolution of iron in nitric acid.

On the whole, I conſider this as a very diſtinct fact in confirmation of Bergmann's ſagacious conjecture, and a corroboration of the proofs which Mr. Berthollet has given of the ſame opinion. I have already mentioned ſeveral of them, in my account of hydrogen, drawn from

a variety of ſources. I believe I forgot to mention a very diſtinct one, which, I think, admits of no other explanation. When the vapour of oxygenated muriatic acid is paſſed through the pure vapour of volatile alkali, both diſappear, and we get a watery ſolution of common muriatic acid, and a quantity of azotic gas; and heat is produced. The redundant oxygen of the muriatic acid attracts the hydrogen of volatile alkali, and forms water, ſetting the azote of the alkali at liberty. There was nothing elſe in the materials that could yield azote, nor any other way in which it could be detached.

The muriatic acid diſſolves iron with effervescence, occaſioned by the production of inflammable air, which is the ſame in quantity and quality, or very nearly the ſame, with that produced by the ſulphuric acid and iron. When the iron is diſſolved and the acid is ſaturated, we have a ſolution which has a green colour, like the ſolution in ſulphuric acid, and in which there is alſo ſome *plumbago*, which makes it muddy, and muſt be ſeparated by filtration. To have theſe phenomena in the beſt manner, uſe the following proportions: Iron, one ounce; muriatic acid, ſix ounces (equal in bulk to $5\frac{1}{4}$ of water); and add $2\frac{1}{2}$ ounces of water. Thus we have it of a clear green. It readily affords cryſtals of the ſame colour.

Theſe cryſtals are not affected by heat in the ſame manner as the vitriol or ſulphat of iron. We can gradually expel the ſulphuric acid from iron, by the force of heat, and the iron remains in the ſtate of an oxyd. But when we attempt to expel the muriatic acid in the ſame manner, a great part of the iron is volatilized by it. Thus, if we expoſe a compound of iron and muriatic acid to heat in a retort, and gradually increaſe the heat to the greateſt degree which the retort can bear, no part of the acid ariſes pure; but what riſes firſt, however, is leſs charged with iron, and condenſes into a yellow liquor. What follows this is combined with more iron, and condenſes into ſhining deep yellow or black ſcaly cryſtals, in the neck of the retort. In the bottom of the

retort remains a maſs, concreted into ſcaly cryſtals *. It conſiſts of a greater part of the iron, retaining a portion of the acid, but not enough to give it volatility. All this agrees with other phenomena, in ſhewing that metals have a ſtronger attraction for the muriatic acid than for either of the other two foſſil acids.

The muriatic acid diſſolves iron readily alſo, when this acid is combined with water in its oxygenated ſtate; but then there is no effervescence of inflammable air. The only effects produced are, that the iron is calcined and diſſolved, and the acid returns to the ſtate of common muriatic acid. The ſolution is, therefore, not different from one produced by diſſolving iron in common muriatic acid, excepting that no inflammable air is produced. The reaſon is evident. The oxygenated muriatic acid contains plenty of oxygen to ſatisfy the attraction of the iron for this principle. No part of the water therefore is decompoſed, nor any inflammable air produced from it. In this reſpect, the oxygenated muriatic acid is ſimilar to the nitric acid,—in the action of which upon metals inflammable air is never produced.

Thus, I have deſcribed the action of the three foſſil acids on iron, when applied to this metal in its ordinary metallic ſtate. If the iron be previouſly calcined before theſe acids are applied to it, it can be diſſolved by them in this ſtate alſo, but with more difficulty, and in leſs quantity; much more acid being required to diſſolve an ounce of calx than an ounce of iron. And ſuch diſſolutions are performed without effervescence, except when the calx happens to be combined with carbonic acid.

The muriatic acid diſſolves the calcined iron better than other acids. But even of this acid a much greater quantity is required to diſſolve calcined iron than metallic iron, and always a greater quantity in pro-

* This ſublimate is deliqueſcent. When mixed with thrice its weight of ſulphuric æther, and digeſted, the æther takes all the colour to itſelf. Seven parts of alcohol added to this, forms Beſtuſcheff's drops, a medicine of high character on the Continent. It becomes colourleſs by a few minutes expoſure to the ſun's light.

EDITOR.

portion as the iron is more calcined. The colour of the ſolution alſo is different from that of the ſolution of metallic iron. Inſtead of being green, it is yellow. There is no inflammable air produced on this occaſion: nor is it to be expected, for the iron being uſed in the ſtate of a calx, or already combined with oxygen, has no power to attract oxygen from the water, or to decompoſe any part of it.

This yellow colour, which is very like that of the ſolution of gold, has often miſled viſionary and ignorant chemiſts, and made them imagine they had diſcovered gold in earths and ſtones, and other minerals, of which there are a great number containing iron in the ſtate of a calx, and therefore diſpoſed to diſſolve in muriatic acid, and to tinge it of the ſame yellow colour.

The vegetable acids act alſo on iron, and by uniting with it, give it a ſoluble ſaline form. But they diſſolve it much more ſlowly than the foſſil acids, and require to be aſſiſted by digeſtion. They produce ſolutions of a green colour at firſt, but changing, by time and the action of the air, to a ruſſet, or ruſty colour. This, or ſome ſimilar change of colour, happens to all the ſolutions of iron, when they are kept for ſome time, and eſpecially if they are expoſed to the air. And if they were ſaturated with the iron at firſt, they are ſure to depoſit a part of it, in the form of ochre, or of a ruſty coloured calx. Fourcroy ſays that the calx of iron, diſſolved in the acetous acid, gives us a ſolution of a fine red colour. The ſeparation of part of the iron in this manner is much promoted by boiling ſuch ſolutions in an open veſſel, or by evaporating and diluting them repeatedly. By adding more acid, we can in moſt caſes rediſſolve the iron or calx, which is ſeparated, and make the ſolution clear again.

I have been long accuſtomed to explain this ſeparation of part of the iron from its ſolutions and change of colour which theſe undergo, by ſhewing that it proceeds from a farther oxydation which happens to this metal after it is diſſolved. During the effervеſcence which appears while the iron is diſſolving in the ſulphuric or muriatic

or acetous acids, this metal is oxydated to a very moderate degree only; but after it is diſſolved, it undergoes a farther oxydation. The diſſolved iron continues to act ſtill, though much more ſlowly than at firſt, upon the water, and to attract oxygen from a ſmall part of it, or perhaps from the air contained in the water. And the iron, by becoming more oxydated, has its attraction for acids diminiſhed. It requires a greater quantity of the acid to keep it diſſolved. Hence the quantity of acid which was ſufficient at firſt is inſufficient afterwards; and ſome of the moſt oxydated part of the iron ſeparates in form of ochre or calx.

That this is a juſt account of the phenomena is proved by ſeveral facts. 1*ſt*, Recent ſolutions of metallic iron emit an odour of inflammable air, and continue to emit it, though not ſo ſtrongly, for a long time after they are made. 2*dly*, Changes of colour, which happen in them by keeping, are always ſuch as to end in the colour produced by diſſolving a calx in the ſame acid. 3*dly*, An old ſolution, which has ſuffered this change of colour, will reſume its primitive colour, if ſome freſh iron be diſſolved in it by means of a little additional acid. The freſh iron, while diſſolving, reduces the other to a leſs calcined ſtate, by taking from it a part of its oxygen. 4*thly*, The calces of iron, otherwiſe produced, are well known to be leſs diſſoluble than iron. They require a greater quantity of acid to diſſolve them, in proportion as they are more calcined. And they have much leſs attraction for acids than iron has which is leſs calcined.

From this change which happens to the ſolutions of iron, you will eaſily underſtand the origin of the great quantity of ochre, or yellow calx of iron, which mineral ſprings, containing vitriol of iron, depoſit in their courſe. In the ſame manner is produced the durable yellow ſtain which all the ſolutions of iron leave upon white cloths, on account of which ſome are uſed in painting linens. The metal is introduced in a diſſolved ſtate into the very ſubſtance of the fibres, and there, by the action of air, which calcines it to a great degree, it is

depoſited in the form of ochre, which never can come out until it is again diſſolved. This alſo points out the proper method of removing thoſe ſtains, viz. by applying ſuch acids as can ſafely be uſed to re-diſſolve the iron. The muriatic acid is the moſt powerful diſſolver of the calces of iron; and when applied weak, effectually takes out the ſtain, without injuring the cloth in the leaſt. Some vegetable acids alſo, ſuch as the acid of tartar, are very effectual; and even the ſulphuric acid may be uſed for this purpoſe, if applied with caution, and in a proper ſtate of dilution. The nitric acid has little action upon the calces of iron: It is rather diſpoſed to render them more difficult of ſolution; and is actually employed for this purpoſe in ſome proceſſes.

You will alſo underſtand the propriety of the proceſs given in the laſt edition of the Edinburgh Pharmacopœia for *Tinctura Martis* *.

Alkalis in their ordinary ſtate ſhew little power to act upon iron. We commonly evaporate watery ſolutions of the alkalis in iron veſſels, when we wiſh to have the alkalis in a dry ſtate; and they neither corrode the iron nor are ſenſibly tainted by it. If we add alkalis to ſolutions of iron in acids, they precipitate the iron. If the ſulphat of iron is recently made, the precipitate is bluiſh green. It is in that ſtate of very moderate oxydation to which the iron was reduced during its diſſolution. But if it ſtand a while expoſed to the air, or when the water in which the precipitation is performed contains plenty of good or reſpirable air, the precipitated metal attracts more oxygen, and changes its colour, and becomes ochry or ruſty coloured. Scheele found that the rapid exhibition of this colour was the ſureſt teſt of the preſence of vital air in water. (*On Fire*, &c. No. 94.) It is evident that the yellow colour which the oxyd aſſumes is in conſequence of its becoming more oxydated, or abſorbing more vital air. It is alſo very much diſpoſed to abſorb carbonic acid, when in this ſtate.

In ſome caſes of the precipitation of iron by an alkali, the precipitate can be re-diſſolved by adding more alkali. The moſt noted ex-

* Vide Diſpenſatory.

ample of this is in the precipitation and rediſſolution of the nitrat of iron. The blood red ſolution thus obtained is called the *tinctura martis alkalina* of Dr. Stahl.

But among the moſt remarkable effects produced by alkalis on the ſolutions of iron, are thoſe of the PRUSSIAN ALKALI, or LIXIVIUM SANGUINIS.

Lixivium Sanguinis.

This is a preparation of alkali diſcovered by a Pruſſian chemiſt named Dieſbach. He evaporated blood to dryneſs, and mixed it with half its weight of fixed alkali; and roaſted or charred the mixture with a ſtrong heat, till little or no more fumes aroſe from it. He diſſolved this charry matter in water, and filtrated the ſolution, which had a deep brown colour, and a ſtrong diſagreeable ſmell. When the lixivium is thus cleared of impurities, and brought to a proper degree of concentration by boiling, it is then called LIXIVIUM SANGUINIS, PREPARED ALKALI, and PRUSSIAN ALKALI.

If this lixivium be dropped into a freſh made ſolution of iron in ſulphuric acid, to which a few drops of muriatic acid have been previouſly added, we ſhall ſee each drop of the lixivium produce a fæcula of the moſt rich and beautiful blue, which will ſlowly deſcend to the bottom, and there collect. It may be ſeparated by decantation, and repeated waſhings with water. Without the muriatic acid, it is generally tainted with a brown or yellow ochry matter. This fæcula is manufactured for a pigment, by the name of PRUSSIAN BLUE.

The moſt minute quantity of iron in a mixture becomes diſcernable by this addition, which is therefore a trial of the preſence of iron in mineral waters.

The colour of this precipitate is not liable to fade in the air; neither is it altered by diluted acids. It manifeſtly depends on a matter which is joined to the iron, and precipitates with it; the iron having received it from the alkali by a double elective attraction; the alkali combining

at the ſame time with the acid which had diſſolved the iron. Theſe are the manifeſt facts.

This is further proved by an experiment deſcribed by Mr. Lewis, in his *Materia Medica*, and alſo by Macquer. In this experiment, this blue precipitate is decompounded by digeſting it with a diſſolved alkali. The iron is ſuddenly deprived of its colour, and the alkali ſhews that it has attracted a part of the tinging matter, for it will now precipitate iron blue. This ſhews that a particular matter is combined with the iron in the blue precipitate, which matter can be taken from it and reſtored again.

A careful examination of the phenomena in this experiment ſhews that, on the one hand, the alkali poured on the Pruſſian blue not only abſtracts the colouring matter, but alſo diſſolves ſome of the oxyd of iron; for an acid added to it will make it depoſit ſome Pruſſian blue. This ſeems to happen, becauſe the added acid firſt diſſolves this oxyd, and the ſolution is immediately acted on by the Pruſſian alkali, and thereby precipitated blue.

On the other hand, there is the ſame evidence that the ochry matter left by the alkali is not an ordinary calx; for when an acid is poured on it, we have a blue precipitate. Mr. Berthollet ſays, that after repeatedly waſhing the calx left by the alkali, with water, which comes off clear, we ſtill at laſt obtain a blue precipitate. How this is produced will be explained afterwards, but in the mean time, we ſee that ſome of the tinging matter remains combined with the iron.

Therefore the alternate treatment with acids and alkalis, and the concomitant production and removal of the blue precipitate, muſt have a period; we ſhall ſee preſently that the colouring matter is ultimately decompoſed by this treatment.

But we have alſo learned by experiments that there is not enough of this matter in the lixivium ſanguinis, as it is uſually prepared, to convert the whole of the precipitated iron into blue precipitate, and that a good deal is in the ſtate of an ordinary oxyd. Hence we per-

ceive the uſe of the muriatic acid in preparing the blue precipitate. It is neceſſary for re-diſſolving that part of the iron which is precipitated in the form of ordinary calx, and which ſpoils the colour. There is no danger that the acid will diſſolve any part of the blue precipitate: It reſiſts the action of acids in their diluted ſtate.

The nature of this matter which is joined to the iron in the blue precipitate is ſingular and ſurpriſing. It appears to be a ſort of ammoniacal compound. It contains a volatile alkali intimately combined with a very peculiar volatile matter, which is inflammable; the vapour of it readily taking fire, while at the ſame time, it partakes alſo of an acid nature, or has an attraction for alkalis, alkaline earths, and metals.

But when this acid ſort of matter is combined with alkalis alone, it adheres to them with a force which is very weak. It diminiſhes very little their alkaline qualities, and is eaſily ſeparated from them by the weakeſt acids, even by fixed air. There is only one way by which it can be made to adhere ſtrongly to the alkaline ſalts, that is, by adding to the compound ſome of the metallic ſubſtances, particularly iron very ſlightly oxydated. A ſmall quantity of the iron is diſſolved by the compound of alkali and tinging matter; and thus is formed a compound of three ingredients, all of which cohere together much more ſtrongly than the volatile tinging matter and the alkali did before by themſelves. Mr. Macquer firſt gave us ſomewhat of a diſtinct notion of it, by demonſtrating the double exchange which happens in the formation of the blue precipitate. Mr. Scheele diſcovered the particular ſubſtance in which the colouring power reſides, and inveſtigated ſeveral of its chemical relations. His experiments are to be ſeen in his chemical eſſays, tranſlated by Dr. Beddoes, 1786. Mr. Berthollet proſecuted the diſcovery of Scheele, and has greatly added to our knowledge of this remarkable ſubſtance.

The triple compound I juſt now mentioned is formed at once, either by adding a calx of iron to the lixivium ſanguinis, or by mixing a ſolution of pure fixed alkali with the blue precipitate, as in that

experiment I mentioned a little ago; and thus the alkali can be completely ſaturated and neutralized. The ſolution of it in water has a yellow colour, from the iron which it contains. It can be ſeparated from water by evaporation, and in ſome meaſure cryſtallized into flakes or ſcaly cryſtals; or it may be made to ſeparate from the water, and to cryſtallize ſuddenly by means of alcohol. If into a ſaturated ſolution of Pruſſian alkali, ſomewhat inſpiſſated and filtrated, we pour an equal meaſure of alcohol, the mixture becomes immediately thick by ſhaking, and the precipitated matter appears a ſoft granulated ſubſtance, like ſoaked rice. By long keeping, ſome ſpirit ſeparates to the top, and the granulated matter becomes ſcaly.

I ſaid juſt now that the common proceſs for preparing the Pruſſian alkali is to mix the alkali with dried ox-blood, and burn the mixture to a charcoal, from which the alkali is extracted with water: But ſeveral other ways to prepare this alkali have been diſcovered.

All the animal ſubſtances, from which a volatile alkali can be formed or extricated by heat, will ſerve as well as dried blood to be mixed and charred with the alkali. Horn ſhavings, hair, wool, pounded bones, &c. are extremely fit for this purpoſe. And Mr. Scheele prepared a very good Pruſſian alkali, by making fixed alkali and charcoal duſt red hot, and then thruſting down a little maſs of ſal ammoniac to the bottom of the crucible, and continuing the mixture for a ſhort while in a low red heat. This ſhews that a volatile alkali is neceſſary to the production of this tinging matter *.

This effect of the lixivium ſanguinis on ſolutions of iron is the foundation of the art of preparing the colour called Pruſſian blue, for painters, and other artiſts. The chemiſt who firſt diſcovered it lived at Berlin, and kept it ſecret for ſome time, that he might ſell the blue at an high price; and hence it is called Berlin, or Pruſſian blue. Many chemiſts have made experiments on it, and endeavoured to inveſtigate

* A mixture of chalk with the ſal ammoniac greatly improves the proceſs, and is the moſt certain and expeditious method for obtaining Pruſſian alkali. EDITOR.

the nature of it, and to improve the art of preparing it, of which you may ſee many examples in the Memoirs of the Academy of Sciences; but the greateſt progreſs has been made by Mr. Macquer, by Scheele, and by Mr. Berthollet. (See *Dictionary of Chemiſtry*, *Scheele's Eſſays*, and the *Annales de Chymie*, alſo *Note* 18. *at the end of the Volume.)*

I muſt not, however, omit informing you that the Pruſſian blue of the ſhops has other ingredients beſides the vitriol and Pruſſian alkali. This would produce a pigment almoſt black, ſo intenſe is its colour. A great quantity of alum is uſed in the preparation. Its acid adheres very looſely, and ſaturates the alkali which is not already combined with the Pruſſic acid. Of this there is always a great portion, even after the moſt careful preparation. The alum being thus decompounded, its earth, which is a ſnowy white, dilutes the intenſe blue, without diſcolouring it. It is better liked in this ſtate: But ſurely the painters will find it much leſs powerful in mixture with other colours.

Mr. Macquer contrived a very ingenious method of depoſiting this moſt beautiful colour on cloth, paper, &c. The ſtuffs are firſt ſoaked in a ſolution of vitriol and alum. When thoroughly impregnated, they are dipped in the lixivium of Pruſſian alkali. Any ochry matter in the precipitate may be removed by dipping into a vitriolic or muriatic acid, greatly diluted.

Such are the different ways of precipitating iron from acids by alkaline ſalts. We may next ſubjoin to theſe precipitations an account of the effect of aſtringent vegetables upon the ſolutions of iron.

By aſtringent vegetables are meant ſuch whoſe juices have the power to contract animal fibres, and which, when taſted, occaſion a ſenſation in the mouth as if they produced that effect there. They ſeem to draw the mouth together. More or leſs of this quality is found in a great number of vegetables. It is remarkable in ſloes, and many other unripe fruits, and in all parts of the oak,—the leaves, the bark, the juices, and the galls, which are a tumour produced by extravaſation of juices. Galls are the moſt powerful aſtringents.

If a decoction of any of thoſe vegetables be thrown into any ſolution of iron in an acid, the mixture immediately becomes a dark blue, or black, and its tranſparency is greatly diminiſhed. This may be called a precipitation, although a great portion of the black fæcula will remain ſuſpended for any length of time in cloſe veſſels; for the greateſt part of it may be ſeparated by filtration.

I introduced the mention of this effect of aſtringents among the precipitations of iron, becauſe, although it is not commonly a precipitation, but generally a mere change of colour, eſpecially at firſt, there are however ſome aſtringents, logwood, for example, that actually ſeparate the iron from the black ſediment, eſpecially when much diluted. Beſides, a little acid deſtroys the colour, and a little alkali reſtores it: Indicating, I think, that the aſtringent matter was imperfectly ſeparated from the acid,—ſeeing that more acid deſtroys the colour, by bringing the iron into more perfect ſolution. The added alkali reſtores things to their former ſtate, merely by ſaturating the acid.

Theſe experiments ſhew ſome ſort of power in aſtringents to looſen the coheſion of iron with acids. There are other experiments which ſhew that they have a diſpoſition to unite with the iron themſelves, and to diſſolve a ſmall quantity of it. Several chemiſts, therefore, have choſen to conſider the matter which thus affects the iron as an acid; and they have named it the GALLIC ACID, becauſe moſt abundant in nut galls; and they think that the iron has a ſtronger affinity with this than with the ſulphuric acid, and precipitates with it from vitriol.

A ſurpriſingly ſmall quantity of diſſolved iron, and aſtringent vegetable matter, have a perceptible effect on one another in this manner. If a little infuſion of green tea, for example, be ſpilled on a knife, it ſoon becomes tinctured with an inky blackneſs. The aſtringent matter of the tea acts on the knife, and diſſolves a minute portion of the iron, with which it produces that appearance; or if a knife, or any thing made of iron, is laid on a wet table, the table, eſpecially if oaken, is ſtain-

ed black where it is touched by the iron. Hence this experiment too, as well as that with the Pruſſian alkali, is uſed as a teſt of the preſence of iron in mineral waters.

The black colour alſo given to ſilk, wool, leather, &c. by the dyer, depends on this effect of aſtringents and iron. The principal materials employed in thoſe arts are always ſome of the compounds of iron with acids, (generally vitriol or ſulphat of iron) and ſome of the aſtringent vegetable ſubſtances. Common tanned leather requires only vitriol, becauſe it is already impregnated with the juice of oak bark, one of the moſt powerful aſtringents.

We alſo derive from theſe diſcoveries the art of making the ink now uſed for writing, which is an object well worthy the attention of the chemiſt, as upon the perfection and durability of it may often depend the preſervation of important records, or valuable manuſcripts. The art of making good ink has accordingly been ſtudied by ſeveral chemiſts, *(See Caperarius de Atramentis)* and by none ſo thoroughly as by Mr. Lewis, who publiſhed his experiments in his *Philoſophical Commerce of Arts*, to which I refer you upon this article. He found that galls, when found, are the beſt of all the aſtringent vegetable ſubſtances, eſpecially for durability. Logwood concentrated the colour, by combining more iron in the compoſition, by nearly one-fifth. One part of recently made vitriol to three of galls ſeemed the beſt proportion. More vitriol made the writing blacker at firſt, but greatly impaired its power to reſiſt the action of air and light. Gum-arabic both hinders the ink from ſpreading, and proves a varniſh, which defends the compoſition from the air. The ancients wrote with levigated charcoal, the moſt indeſtructible ſubſtance we know; and accordingly, the writings found in Herculaneum are ſtill a perfect black. They were pigments. Their defect is, that being ſuperficial, they may eaſily be eraſed, whereas the ink of modern times penetrates into the paper. Dr. Lewis combined the two inks very ſatisfactorily, by mixing ſome fine lamp black with his ink, in ſuch quantity only as to make it very ſenſibly blacker at

firſt. This ink withſtood all action of the weather. It ran from the pen with abundant eaſe. I recommend this paper of Dr. Lewis as being alſo a good example of the chemical inveſtigation of any complicated ſubject, and for many judicious and uſeful incidental obſervations through the whole. I ſhall only add to what he recommends, the uſe of a ſmall quantity of cloves, and to keep the ink in a cool and dark place, and not too long. The reaſon of this laſt caution is, the corruption of the vegetable aſtringent. The effect of the cloves is to retard this, and to prevent the formation of mould upon the ſurface *.

* As vinegar has not the power to diſſolve and diſcolour this black compound, Dr. Lewis recommends vinegar or wine as the beſt ſolvent of the materials. It undoubtedly becomes more durable, but it is found to ſoften the nib of the pen ſo much that it is quickly worn away by the paper. The great art in ink-making is to have a ſuperabundance of aſtringent matter, to counteract the diſpoſition of the iron to a farther calcination, which renders the ink brown. It would be a great improvement in the manufacture of writing paper, if ſome aſtringent matter could be introduced. A little ardent ſpirits effectually prevents the ſpoiling of ink by keeping, but makes it ſink and ſpread. Corroſive ſublimate prevents mouldineſs *completely*.

A good proportion for writing ink.

Raſped logwood	1 ounce.
Beſt gall nuts in coarſe powder	3 ounces.
Gum-arabic in powder	2 ounces.
Green vitriol	1 ounce.
Rain water	2 quarts.
Cloves in coarſe powder	1 drachm.

Boil the water with the logwood and gum to one half; ſtrain the hot decoction into a glaſed veſſel; add the galls and cloves; mix and cover it up. When nearly cold, add the green vitriol, and ſtir it repeatedly. After ſome days, decant or ſtrain the ink into a bottle, to be kept cloſe corked, in a dark place.

A ruddy friable gum reſin, not unlike gum-kino, from New Zealand, was given me by a friend. Finding its taſte remarkably aſtringent, and the whole very mucilaginous, I mixed ſome of it with ink powders, and found that it improved the ink in a very remarkable manner, both deepening the colour, and giving it body. Writings with it, and with ink made by Dr. Lewis's receipt, on a card, being expoſed to the weather on a ſouth wall, this addition was found to have encreaſed its durability ſurpriſingly.

EDITOR.

Of the compound ſalts, I obſerved formerly that none are ſo remarkable for their effects on the metals as nitre and ſal ammoniac.

Nitre deflagrates violently with iron in a ſtrong heat, and is alkalized, or its acid is decompounded and diſſipated, as in the other caſes of deflagration with this ſalt. The alkali remains mixed with the calx of the metal, and is cauſtic, in conſequence of which it acts on the calx, and unites with a part of it,—rendering it ſoluble in water to a certain degree along with itſelf; but this ſolution is not permanent.

Sal ammoniac and this metal act remarkably on one another. I pointed out the reaſon of this in treating of metals in general, namely, the volatilizing power of the muriatic acid. Common ſal ammoniac contains the acid which has the ſtrongeſt attraction for the metals; and this acid is combined with the weakeſt of the alkaline ſalts,—the alkali which has the weakeſt attraction for acids in general. Accordingly, if we mix together equal weights of ſal ammoniac and iron filings, and grind theſe materials well in a mortar, they ſoon after begin to act;—the matters grow warm,—the more readily, if a little humidity be added. The ſal ammoniac begins to be decompounded; the acid joins itſelf to the iron; and the volatile alkali is detached, and ſhews itſelf in a ſeparated ſtate by its pungent odour. There is alſo ſeparated at the ſame time a quantity of inflammable air, the odour of which mixes itſelf with that of the volatile alkali. This inflammable air is produced by the decompoſition of ſome of the water. The action of theſe materials, and the decompoſition of the ſal ammoniac, are not complete, however, until we apply heat to the mixture in glaſs veſſels. Then the ſal ammoniac is totally decompounded, and a cauſtic volatile alkali riſes, which it is almoſt impoſſible to condenſe completely, on account of its being accompanied with inflammable air. The whole of the acid remains combined with the iron in the retort.

All theſe effects are alſo produced on ſal ammoniac by the calces

of iron, with this difference only, that it requires a larger quantity of the calx to decompound the whole of the ſal ammoniac, and that, during the action of the materials, there is no heat or inflammable air produced.

But when ſal ammoniac and iron are made to act on one another, it is not uſual to take ſuch a large proportion of iron, or of calx of iron, as will decompound the whole of the ſal ammoniac. There is a preparation obtained from ſal ammoniac and iron, ordered in both the London and Edinburgh Pharmacopœias, under the title of FLORES MARTIALES. This is produced by mixing with the ſal ammoniac ſuch a quantity of iron filings, or of a calx of iron, as is ſufficient for decompounding only the half of the ſal ammoniac; and this mixture is expoſed to heat in proper veſſels. Firſt, we get a cauſtic volatile alkali, detached from that part of the ſal ammoniac which is decompounded. After this has come over, the heat is increaſed, to make the entire part of the ſal ammoniac ariſe, which requires a much ſtronger heat. The vapours of it condenſe into a ſolid matter, or what is called FLOWERS; but while it ariſes in this manner, it carries with it a part of the compound of acid and iron that was formed in the beginning of the operation. This compound is in ſome degree volatile, when there is enough of acid combined with the iron. A part of it, therefore, riſes, and is condenſed with the ſal ammoniac, and forms the reddiſh and yellow flowers to which we give the name of *flores martiales*.

It is found that an oxyd, inſtead of the metal in its pureſt ſtate, enſures the deſirable appearance of this preparation,—the red and yellow colour of the flowers. Therefore, when filings of iron are employed, it is of conſiderable uſe to expoſe them for ſome time to the damp air of a cellar. An oxyd ſtill more replete with vital air, ſuch as colcothar is, more certainly produces red flowers. *(See Note 19. at the end of the Volume.)*

Iron in its calcined ſtate can be mixed in fuſion with vitrified earths;

and the glaſs compound is tinged of various colours, according to the quantity of the iron, and the degree to which it is calcined. The colour which this metal moſt readily communicates is a green, like that of its ſolutions in acids. Such a green is ſeen in the common glaſs of which bottles are made, and in crown or window glaſs; and the green phials of the apothecaries are tinged with iron. But when the calx of iron is very highly calcined, it will ſometimes give a dull yellow colour, and a red; and in all caſes, when much of the iron is added to the glaſs, the colour is increaſed or darkened, ſo much as ſometimes to produce almoſt a blackneſs.

It is owing to the preſence of this calx, in ſome degree or other, in almoſt every foſſil body, that our clays are in general ſo much diſpoſed to vitrify, when urged by great heats. A very minute portion of it gives an incipient vitrification to the beſt of them, and produces the compactneſs that is ſo deſirable in all, with very moderate heats. It is this which gives the red colour to our common brick and tile.

Such bricks are unfit for the conſtruction of furnaces, becauſe a moderate heat makes them run into ſlag. The greeniſh yellow colour of the ſmall Dutch bricks is not owing to a want of iron, for they contain a great deal, but to the preſence of magneſia. The greyſtock bricks of London have ſupplanted the red bricks, which are now to be ſeen only in the old houſes, but are inferior to them in their power to reſiſt the weather.

Experiments made with the different earths have ſhewn that the flinty is the moſt diſpoſed of any to unite with calx of iron in the fire, and be melted by it. Hence the uſe of it in welding iron.

The effects of ſulphur and iron on one another deſerve particular notice.

Sulphur unites very eaſily with this metal in the dry way, or by fuſion, as with moſt others. And it penetrates iron more quickly than moſt other metals, ſhewing thereby a ſtronger attraction for it. A

bar of iron, thruſt red hot into melting ſulphur will preſently melt and drop off like wax held in hot water, with a bright dazzling glow.

Alſo, if one part of flowers of ſulphur be ground with five parts (by weight) of fine iron filings, and the mixture be put into a thin glaſs veſſel, ſuch as a matraſs, or cucurbit, and if this be held over clear burning coals, we ſhall obſerve the ſulphur begin to ſhew ſoftneſs very ſoon, ſticking to the ſide of the glaſs, long before the heat has got to that degree that would otherwiſe produce this effect on ſulphur unmixed. It does not riſe much in its temperature for a good while. Then, it ſuddenly becomes fluid all over, and the filings almoſt undiſtinguiſhable; and preſently, the heat riſes rapidly, the maſs fixes, and becomes red hot. This is one of the beſt examples of the emiſſion of latent heat. It takes place when the chemical combination is accompliſhed; and this required previous fluidity. But the temperature is too low for the compound being fluid; it therefore congeals, and latent heat emerges. If there be too much ſulphur, this takes fire. This compound of iron and ſulphur is a hard brittle ſubſtance, of a metallic appearance.

In conſequence of this diſpoſition to unite with ſulphur, iron is often employed to ſeparate ſulphur from other metals, in the way of fuſion. The iron, uniting with the ſulphur, forms a very fuſible compound, which flows uppermoſt: The other metal ſubſides to the bottom.

But beſides the way by fuſion, there is another way of applying ſulphur and iron to one another, ſo as to make them act, It may be called the humid way. The iron is taken in filings, and the ſulphur in powder, and they are mixed together with as much water as makes the mixture into a paſte.

If this mixture be ſhut up cloſely, to prevent its communication with the atmoſphere, the ingredients begin, after ſome hours, to act upon one another,—the iron is corroded into a black mud or paſte, in which the ſulphur and it are ſomehow combined, for the yellow co-

lour of the ſulphur entirely diſappears. This paſte has a ſurpriſingly ſtrong attraction for vital air, and can be employed to abſorb it when we wiſh to know what quantity of vital air is contained in atmoſpherical air, or other ſuch mixtures of different airs. Mr. Scheele uſed it as a eudiometer, in a ſet of experiments which he continued for a whole twelvemonth, to learn what proportion of vital air was contained in the atmoſphere of Stockholm in all the different ſeaſons and months of the year.

A drachm of flores ſulphuris, mixed with two drachms of filings of iron, and as much water as will make it a thick gruel, muſt be put into a little diſh, connected with a piece of cork, ſo as to float on water. If we invert upon this a jar capable of holding 66 ounces of water, (nearly two quarts), all the oxygen contained in the atmoſpheric air, which fills this jar, will be abſorbed by the mixture of iron and ſulphur,—the water of the tub riſing up into the jar, and occupying its place. When the filings are extremely fine and clean, and are mixed with the dry ſulphur by grinding, and then a moderate quantity of water quickly mixed with theſe materials by kneading briſkly, and this preparation put into a hot floating diſh, it will abſorb the vital air ſo rapidly that it will take fire. This may be enſured, by ſmearing with this magma ſome ſmall twigs. This expoſes a great ſurface, and ſoon heats.

If ſome pounds of this mixture are expoſed to the atmoſpherical air, they will attract the vital air ſo faſt from it as to grow hot and to take fire. They grow hot alſo, although they be not expoſed to the open air, if the quantity of them be ſo great as 50 pounds or more; for, in this caſe, there is ſo much air entangled in the paſte in making it up, that the abſorption of this air is enough to produce a conſiderable heat, and even to fire it.

After this abſorption and heat is over, if we examine the remaining matter, we find the ſulphur changed more or leſs into ſulphuric acid, which remains combined with the iron, and forms with it a vitriolic

compound, more or leſs perfect. It is evident that the vitriolic compound is formed in conſequence of the ſtrong attraction, both of the ſulphur and of the iron for the oxygenous principle, which they draw partly from the water, but principally from the air. By this principle the iron is ſlightly calcined, and the ſulphur is changed, at leaſt in part, into ſulphuric acid. The decompounded water, when there is enough of it, gives inflammable air, and the air from which the oxygenous principle is attracted, gives out a great part of its latent heat or caloric, in the form of ſenſible heat, which heats the materials ſometimes to that degree as to make them take fire. When the materials are in large quantity, and covered up, or buried, ſo as to have little communication with the air, there is more water decompounded, and more inflammable air produced. When, on the contrary, the quantity of them is ſmall, and they are confined with a quantity of air, they draw the oxygenous principle chiefly from that air, and decompound the whole air which the veſſel contains *.

A ſimilar change of ſulphur happens in ſome kinds of pyrites, which are natural compounds of iron and ſulphur. And the diſcovery of this has given origin to the art by which common vitriol, or the ſulphat of iron, is prepared in large quantities, and at a cheap rate. I formerly obſerved, that the manner of preparing it, by diſſolving iron in ſulphuric acid, is only practiſed as a proceſs in pharmacy, and the vitriol, or *ſal martis*, ſo prepared, applied only to purpoſes of medicine, but that a much cheaper way of obtaining this compound has long been practiſed, to ſupply the conſumption made of it in ſeveral arts. By this cheaper method, it is prepared chiefly from ſome particular kinds of pyrites, which, when expoſed to the action of the

* Conſult on this ſubject Mr. Lavoiſier's Eſſays, publiſhed in 1777, where the whole procedure is analyſed with great preciſion and diſtinctneſs. Le Sage, *Elem. de Chymie*, i. 42.—Werner on the *Origin of Volcanoes*.—Hopfner's *Magazine of Natural Hiſtory*.—Lemery, *Mem. Acad. Paris* 1700.

air, and of humidity at the ſame time, undergo a change, by which the ſulphur becomes ſulphuric acid, and we get a vitriol, or ſulphat of iron, in place of the pyrites, or compound of iron and ſulphur. Humidity alone is not ſufficient. The pyrites has not the power of decompounding water. Cramer ſays he obſerved immenſe quantities of pyrites all along the Engliſh ſhores, eſpecially about Harwich, which naturally lie in a bed at the depth of ſome feet below the ſurface of the ſand. As long as they lie there, though they are conſtantly wet with ſea water, they continue entire and quite inſipid, but when thrown up to the air by the waves, they are crumbled down, and converted almoſt entirely into a heap of little cryſtals, in a fortnight. This is indeed the caſe every where, for the pyrites is always expoſed to abundance of humidity in the bowels of the earth, but nevertheleſs retains its form until it is dug up and expoſed.

This change, which the pyrites of iron is liable to undergo, is called *vitriolization*,—it is ſaid to *vitriolize*.

It is proper to remark, however, that only particular kinds of pyrites are liable to it, not every kind. Some kinds, ſuchas the cubical pyrites, common in ſlate, and ſome others, withſtand the action of air and humidity a long time without ſuffering a change, or if they are changed, it is very ſlowly, and only into a hard ruſt at their ſurface, but without affording vitriol.

The cauſe of this difference among the varieties of pyrites has not been diſcovered. I ſuſpect that it depends upon the proportion of the ſulphur to the iron, and that thoſe which contain moſt ſulphur are moſt liable to vitriolization.

Proceſs for Vitriol from Iron Pyrites.

The account which I have given you of the chemical procedure will naturally direct you to the proper methods of accelerating the operation. I have only to remark, that ſome kinds of pyrites require a preparation, by roaſting in a heap with a ſmall quantity of fuel. This is found to diſpoſe the harder pyrites to a more rapid decompoſition;

probably opening their texture by the expulſion of ſome of their volatile ingredients.

The pyrites being thus in a proper ſtate for vitriolization, the reſt of the proceſs is the ſame for all kinds. A piece of ground is choſen, having a very gentle declivity, juſt enough to make the water run in one direction. This is laid out in narrow quarters, like a kitchen garden,—the furrows which ſeparate them having the direction of the ſlope. The ground between is covered with firm clay, well beaten, ſo as to be quite impervious to water. The ſurface of each quarter has a ſlope on each ſide toward the furrows. Another furrow is led acroſs the lower extremities of thoſe which ſeparate the ridges; and this furrow terminates in a great ciſtern.

The pyrites, broken into ſmall pieces, are ſpread on the quarters or ridges, and made up into beds about two feet thick. They effloreſce; and the rains waſh off the ſaline cryſtals. The ſolution trickles off into the gutters, which conduct it down the ſlope into the croſs drain, and by it into the ciſtern. In very dry weather it may even be neceſſary to ſprinkle the pyrites on the ridges. As the ſolution is very weak, eſpecially in the rainy ſeaſons, it is frequently thrown again on the vitriol beds by a forcing pump, and it comes off them ſtill more impregnated with the ſalt, till at length it is fit for boiling.

For this purpoſe, it is pumped up into the boiling houſe, which is built over the ciſtern, and is reduced to a ſtrength proper for cryſtallization, by boiling off the ſuperfluous water. From the boilers the liquor goes into the vats or ciſterns, where it is allowed to cool and to cryſtallize.

There are ſome pyrites which are ſo much diſpoſed to vitriolize, that heaps of them are liable to grow hot and take fire; and this has happened on different occaſions to ſome kinds of pit-coal abounding with pyrites, and which had been collected together in large quantity. At Ayr, for example, an immenſe body of coal, built up for exportation, took fire; and in Dublin it happened to a large quantity of Engliſh

coal, which had been provided by the corporation to prevent ſcarcity; and this happened in both caſes after a heavy ſhower. Veſſels loaded with ſuch coal have unfortunately been ſet on fire ſometimes in that way.

In many coal pits the pyritical rubbiſh, which is mixed with the coal, and would ſpoil its ſale, is picked out and left below. When theſe pyrites have been accidentally in too large heaps, they have frequently taken fire, and have ſet fire to the coal works. George Agricola, who wrote in the 15th century, ſpeaks of the fire in the coal-work at Dyſart in Scotland as a very old thing. It is not yet extinguiſhed. At Kilkerran, in Ayrſhire, a very extenſive coal-work has been burning now for fifty years. At Johnſtown, near Paiſley, a ſtratum near ſeventy feet thick was ſet on fire by the rubbiſh, and continued burning with incredible fury, having a great current of freſh air. In one place there was a face of coal red hot for near 100 yards, and the flame aſcended through one of the pits to the height of above 100 feet. It was at laſt extinguiſhed by drowning it; but whenever the air is admitted, it takes fire in a few days.

From ſuch examples ſome have endeavoured to account for hot ſprings, ſubterraneous fires, volcanoes, and earthquakes. They have even attempted to imitate ſome of theſe convulſions of the earth. Lemery was, I believe, the firſt who attempted this imitation. (*See Mem. Acad. Par.* 1700.) It has often been done ſince. The general proceſs has been, to mix as large a quantity as can be conveniently had of clean iron filings, with ſomewhat more of ſulphur, and as much water as will make a firm paſte, and to bury this in the earth, (firſt wrapping it up in a cloth) and ram the earth firmly above it. In a few hours it grows warm, and ſwells ſo as to raiſe the ground. Sulphurous ſteams make their way through the crevices, and ſometimes flames appear. Rarely is there any exploſion; but when this happens, the fire is vivid and brandiſhing,—and the heat and fire continue for ſometime, if the quantity of materials has been great.

We cannot expect more,—we ſee the production of internal heat, ſufficient for more violent operations,—but other circumſtances muſt concur. If water get in by a crevice into a cavern containing red hot materials, there ſeems no bound to the effects which it may produce.

The phoſphorus of urine can alſo be combined in ſmall quantity with iron, by melting the phoſphoric acid with iron and charcoal duſt. The compound is more fuſible than iron, and is not decompounded but with great difficulty, a thing we ſhould not expect of a ſubſtance ſo volatile and inflammable. It makes iron cold-ſhort, that is, it will not bear hammering out when cold, but cracks all over.

Relation of Iron to other Metals.

Iron can be mixed with all the other metals, excepting lead and mercury. It ſhews a diſpoſition to unite the moſt readily and ſtrongly with arſenic, and with the regulus of antimony, and with gold. None of the mixtures of it with metals have been found uſeful, except perhaps manganeſe, which is ſuppoſed to improve iron, but its effect is not ſufficiently aſcertained by experiments.

Iron is, in general, much impaired in its moſt valuable qualities, coheſion, malleability, and toughneſs, by any metallic mixture. Arſenic in particular unites moſt readily, and adheres moſt obſtinately, and makes it red-ſhort, that is, apt to crack under the hammer while forging, and even to fall in pieces.

Ores of Iron.

Iron is ſeldom found pure and metallic, but examples of this however have occurred. A maſs of 1600 pounds weight was found in Siberia: Its interſtices were all filled up with glaſs, of a beautiful bright green, and ſo friable as not to cut the fingers. This circumſtance ſhews that it has been the effect of fire, andthat the glaſs has been quenched in water while yet red hot. Another maſs, much larger, has been found in Paraguay. Such maſſes are ſaid to be not uncommon in Senegal.

(*See Note* 20. *at the end of the Volume.*) Mr. Margraaf has found malleable iron in ſtrings at Eibenſtock in Saxony. Theſe are the only known inſtances; but the ores of this uſeful metal are plentiful in all parts of the world. And beſides, iron is found mixed with many of the other productions of nature, ſuch as the ores of other metals, coloured clays, and boles. Indeed few earths are free from it. The garnet, the emerald, the ruby, topaz, ſapphire, and amethyſt, appear to derive their colours from it. It is found even in the aſhes of vegetable and animal ſubſtances,—in the blood, milk, fleſh, and hair. It has been found in plants which have been raiſed from a ſeed in diſtilled water. Some foſſils containing iron are of great uſe, although not as ores of iron, ſuch as emery for the lapidary; hæmatites for the burniſhers; the red, yellow, and blue ochres for the painters; and the loadſtone for the navigators.

As the ores of iron are very common, only the richeſt or moſt profitable are wrought. In this country, the minerals melted to extract iron from them are diſtinguiſhed into three kinds.

1*ſt*, Iron ores found in veins.

2*d*, Iron-ſtones, interſperſed through ſtrata, or forming thin ſtrata among others.

3*d*, Bog ores, intimately blended with clay, and with the remains of animal and vegetable ſubſtances; not mixed, but in many caſes chemically combined.

All theſe are in general oxyds of iron, in different ſtates of oxydation; and ſome are combined with fixed air, and with ſmall quantities of ſome of the earths. When they are much oxydated, and nearly pure, or with very little of the earthy ſubſtances combined with them, they have a dull and deep red colour, which is the natural colour of the oxyd of iron highly oxydated. Or if ſome fixed air be united with them at the ſame time, they are yellowiſh: Theſe are the ſpathoſe ores of iron, or carbonats of iron. If, on the contrary, they contain the iron but little oxydated, they are grey or black, or approach by

their colour to iron itſelf. They are alſo variouſly cryſtallized; of theſe the bloodſtone, or hæmatites, is the moſt beautiful. Their appearance is alſo very much affected by the mode of their concretion, and by the admixture of earthy matter. White ores and micaceous ores often contain manganeſe, and are thought to yield excellent iron.

The hard pyrites, though it contain much iron, is not treated as ſuch: It is conſidered only as an ore of ſulphur.

To extract the iron, the minerals are firſt roaſted. This operation appears to be neceſſary or uſeful, in extracting iron from many of the minerals from which it is got. It is probably uſeful by expelling ſulphur or ſulphuric acid.

The next operation is to reduce the roaſted ore to a metallic ſtate, or metallize it completely.

This is done in a high furnace, ſhaped internally ſomewhat like two round crucibles joined by their mouths, the uppermoſt without a bottom. The bottom of the furnace is hollow, having on one ſide a hole through which the blaſt of a bellows can be directed a few inches above the bottom. On the other ſide is a larger hole, through which the melted metal can run entirely off. A heap of bruſhwood is thrown into the furnace. It is kindled, and immediately covered with charcoal or coak; and then baſkets of ore and fuel are added till the furnace is filled,—the bellows being worked all the while. The tap-hole of the furnace is ſhut up with clay. Every thing being looſe and open, the flame is forced by the blaſt of the bellows through the whole furnace, and a violent heat is raiſed all over it. As the fuel conſumes, the matters ſubſide; and baſkets of ore and fuel are repeatedly thrown in to fill up the furnace. The earthy matters and ore are melted by the intenſe heat into a glaſs; and ſince the burning fuel is every where in contact with the ore, and the coal has a much greater attraction for the oxygen than the iron has, the metal is reduced, and ſinks to the bottom of the furnace under the melted glaſs produced by the fluxing of the earths. The metal is now defended from the action of the

bellows. When the workman thinks that there is enough collected, he makes a hole in the clay with the tap-iron, and the metal runs out, and is followed by the glaſs or ſlag.

A conſiderable quantity of limeſtone is mixed with the ore in this operation; ſeldom leſs than one-ſixth of the ore. Its uſe is partly to promote the fuſion of the earthy matters mixed with the metalline oxyd, and partly to combine with the ſulphuric and ſulphurous acid; by which means it is carried off in a vaporous form, but takes with it ſome iron. It is thought that a better quality of iron is obtained by the large uſe of lime, even when not required as a mere flux.

It is alſo found, in all caſes, of great advantage to the quality of the iron to uſe a very great quantity of fuel. This, unqueſtionably, produces a more complete abſorption of the oxygen and reduction of the metal. A great allowance of fuel brings more metal from the ſame ore, and makes it more fuſible after repeated meltings. It is very grey, ſhewing ſhining black facets, and talky-like matter, and is ſofter and eaſier cut than white caſt-iron which has been made with leſs fuel. But the room occupied by the fuel cauſes the furnace to produce leſs iron per day; while the blaſt or quantity of air conſumed remains the ſame. Therefore, this iron is much more coſtly. In the Scotch furnaces, the iron-ſtone requires between three and four times its weight of ſoft pit-coal, and each ton of iron produced requires the conſumption of 672,000 cubic feet of common air. Some fuels, particularly blind-coal, require much leſs. Much more is required in ſummer than in winter.

The quality of the iron is affected alſo by the nature of the fuel. Wood charcoal is beſt for producing iron to be refined and made into bars. Charred pit-coal is beſt for iron to be employed in caſt work.

When firſt melted down from the ore in the great furnaces, the metal is in the ſtate called pig-iron, or pot-metal, and is fit for caſt work; in which ſtate it is perfectly fuſible, but is either quite inflexible and brittle, or has very little flexibility and toughneſs. It is uſeful, however, for many purpoſes. In conſequence of its fuſibility, it

can be caſt in moulds, to form large maſſy pieces, and inſtruments of a very great ſize, which are thus formed at a far leſs expence than if it were neceſſary to forge them; beſides that ſome, on account of their large ſize, could not be forged. But fuſible iron is unfit for anchors, and other ſuch inſtruments, which muſt be exceedingly ſtrong and tough.

I ſhould obſerve, in this place, that the caſt iron obtained by this proceſs appears in three ſtates, which are very diſtinguiſhable, both in appearance and qualities, according to the manner in which it has been manufactured.

1*ſt*, WHITE CAST-IRON, extremely hard and brittle. It can not be filed, or bored, or repaired in any way, nor bend. It cannot bear very ſudden changes of temperature, without cracking. Its ſtructure is cryſtallized, with very ſmall brilliant facets.

2*d*, GREY CAST-IRON, of a granulated texture, and often plated, but of an unequal dull colour. It is much more coheſive than the former; and is therefore employed for artillery. It is alſo ſofter, and may be cut and bored, and even turned in a lathe.

3*d*, BLACK CAST-IRON, the moſt unequal in its texture, the moſt fuſible, and therefore often mixed with the white to make it ſtand a repeated melting. It is leſs tenacious than either of the former.

The firſt ſeems to contain much unreduced oxyd, and even ſome earthy matters, which vitrify along with it. Theſe are entangled among the truly metallic parts, and thus defend them from the action of the air. The ſecond kind has little unreduced oxyd, or earthy matter, having been prepared with more fuel and greater heat, but there is more of the inflammable matter of the fuel combined with it. The laſt alſo contains much of this, and derives other varieties from the nature of the ores. It makes the beſt refined or malleable iron.

Iron is changed from this fuſible and rigid ſtate into tough and malleable iron, in the forge, or finery as it is called, and by an operation which is conſidered as a refinement of it.

Until lately, the only manner of performing this operation was by heating two or three hundred weights of it at once, in a hollow forge, in which the iron was covered with a fire of charcoal, and lay in a bed of charcoal duſt and aſhes until it juſt melted, with no more heat than what was barely ſufficient; and it was kept in this heat for ſome time, —the wind of the bellows being directed through the charcoal, ſo as to have ſome effect on the ſurface of the metal; and being ſtirred now and then, it was taken out a toughiſh cavernous maſs, and was compacted by hammering.

But within theſe few years another proceſs was contrived by a Mr. Cort, which admits of an immediate inſpection and examination of all the phenomena; the metal not being covered with the fuel, but expoſed to the view of the operator and obſerver.

Here the iron is melted in a reverberatory furnace, and a ſtrong flame is kept blowing over it, ſo as to keep it in a moſt intenſe heat. It is all the while ſtirred about with a rake, ſo as to bring every part of it to the ſurface in ſucceſſion. By this treatment certain impurities of the iron are diſſipated in a way that we do not yet underſtand. The fact is, that it gets into a particular ſtate, which is indicated without any danger of miſtake, by the iron becoming thick like gruel, ſwelling up a little, and the ſurface of it all at once becoming of a dazzling brightneſs, by a low flame which gleams upon it. It is now ſaid to be *brought into nature*.

When the iron is thus *brought into nature*, that is, has loſt its fuſibility, and is become malleable, it is collected into two maſſes in the *laboratorium* of the furnace, by raking it together, and compacting it with the ſtrokes of an iron club or mace. Theſe maſſes are called *loops*. They are very porous and ſpongy, and contain a great deal of ſcoriæ, or ſemi-vitrified matter, mixed with the iron. The heat to which they are expoſed is then increaſed for a ſhort time, until theſe ſcoriæ are completely melted, at which time the loop is taken out, and

immediately expoſed to the ſtrokes of a large and heavy hammer, wrought by a water wheel or ſteam engine. This compreſſes the maſs, unites the parts of it more cloſely, and forces out the greater part of the vitrified matter, or *finery cinder*, as it is called, out of its pores. The maſs is turned under the hammer, until it is formed into a ſhort and thick priſm or cylinder called a *bloom*, the parts of which are not yet ſo cloſely united as they ought; but by heating it again, and ſubjecting it again to the great hammer, or paſſing it between rollers contrived for this purpoſe, the parts of it are made to enter into cloſe coheſion, the liquid droſs completely ſqueezed out of its pores, while it is at the ſame time forged into bars of different kinds.

The iron made by this proceſs, from very ordinary iron, ſuch as was known to yield bad bar iron, proved equal to the beſt Swediſh iron. Very ſevere trials were made by Government, as it was recommended for the uſe of the navy, for anchors, bolts, ſtraps of blocks, and other uſes, where toughneſs was an indiſpenſable requiſite. But, to make bad iron ſo eminently good, required much labour and expence. Caſt iron, which yielded better bar iron by the uſual proceſſes, was amenable to the ſame degree of fineneſs with much leſs trouble. I mention this circumſtance, to ſhew that the proceſs is general, and depends on principle.

By this proceſs, the expence of wood charcoal, which is a very dear fuel in this country, is ſaved; the whole operation being performed by the flame and heat of pit-coal.

By whatever proceſs fuſible iron is refined to the ſtate of tough iron, a conſiderable part of it (one-third commonly) is ſcorified or calcined, forming a fuſible calx or oxyd, called FINERY CINDER. It is exactly ſimilar in its appearance to the fuſible oxyd formed from iron when it is burnt in vital air. The production of this finery cinder is abſolutely neceſſary; and the ſkilful workmen ſay, that for the right performance of this proceſs, it is neceſſary that the refining iron

be well ſoaked, and mixed to a certain degree with this finery cinder; for which reaſon, although they let ſome of this cinder run out at a tap-hole of the furnace or forge, when it accumulates too much, they never let it all run out, but retain a proper quantity in the furnace or forge all the time they are working.

But it is alſo certain that the iron loſes a quantity of inflammable matter, which is contained in it while in its hard and brittle and fuſible ſtate.

When we try to diſſolve fuſible iron in acids, we find it more difficult to diſſolve it, and there is an incomparably greater quantity of plumbago left from it than from tough iron. You know that plumbago is principally compoſed of carbon, or carbonaceous matter; but there is, beſides, often ſome ſulphur or ſome phoſphorus. The change of fuſible into malleable iron appears, therefore, to depend chiefly on the deſtruction of the plumbago, or of the greater part of it. And it is eaſy to ſhew in what manner this happens in the refinement of iron. Dr. Beddoes has endeavoured to explain how it happens in Mr. Cort's proceſs, and he has explained it in ſome meaſure, but aſſumes a principle which I cannot admit.

The principle aſſumed by Dr. Beddoes and the French chemiſts is, that the unrefined fuſible iron, beſides containing a quantity of carbon, alſo contains iron in the ſtate of an oxyd, and that the oxygen of this ill reduced iron acts on the carbon, and produces the increaſe of heat, and the intumeſcence, or fermentation, and the eruption of elaſtic fluid and of flame.

But it always appears to me inconceivable, that there ſhould be preſent in fuſible iron, at the ſame time while it flows white hot from the great furnace, both an abundance of carbon and an oxyd of iron, without acting on one another originally, eſpecially in the grey iron, which moſt abounds in carbon.

There is no occaſion for having recourſe to ſo unwarrantable a ſuppoſition. It is evident that the effect of a great part of Mr. Cort's

proceſs is to calcine a part of the iron in the firſt place. While the workman is buſily employed in ſtirring it over from one ſide of its bed to the other, ſeparating it into ſmall parts, and mixing the whole carefully together, a quantity of the iron (to which the air is admitted all the while) muſt be calcined or oxydated; he then increaſes the heat a little, to make the oxygen of this calcined iron act on the carbon of the uncalcined. This increaſes the heat in the iron, and produces the fermentation, or formation of carbonic acid gas, which, while it riſes, carries ſome carbon with it,—and hence the blue flame. The nicety of this operation depends on knowing how far to carry the calcination of part of the iron, that there may be enough of oxygen to conſume the whole of the carbon. If more iron than enough be calcined, it is ſo much loſt.

Such a perſuaſion ſuggeſted to Mr. Reaumur a project to ſoften or give toughneſs to caſt iron by cementation. He conceived iron to differ from other metals by combining with much more inflammable ſubſtances than was neceſſary for its ductile form, and expected to abſorb or conſume this by proper ſubſtances. He therefore cemented caſt iron with earthy powders; and after the cementation is carried a certain length, the iron yields to the file, if ſlowly cooled, but if tempered, is quite hard. It has ſome malleability when red hot, but none when cold. If it be ſtrongly heated, it flies to pieces under the hammer. Thus it plainly reſembles ſteel. Continuing the cementation longer, it becomes now ſo ſoft as to be eaſily cut, filed, bent, or forged, and does not become much harder by temper. In proportion as it becomes ſoft, it loſes its fuſibility, and the internal parts can be melted out; ſo that in every reſpect it is ſimilar to forged iron, only it is not ſo compact or ſolid. All theſe changes ſeem accountable by a gradual exhalation of the carburet included in the crude iron. This may be aſſiſted in Reaumur's proceſſes by the cementing matters, either by their abſorbing this matter as it exhales or comes to the ſurface, or perhaps diminiſhing the attraction, by preſenting to the

iron or the carbon ſome vapour for which they have ſome attraction. But we do not know any matters that are much preferable to others which are not obviouſly improper. Though Mr. Reaumur did not ſucceed in eſtabliſhing ſuch an art in France, it is now practiſed in Britain.

The very beſt kinds of refined, or bar iron, are very ſtrong and tough when cold, and bear to be bent backwards and forwards very much before they break, and they are alſo very malleable when hot. Sweden is remarkable for producing iron, from ſome of its ores, of this very beſt quality. But the greater number of iron ores do not produce iron ſo good, though it be good enough for common uſes.

The blackſmiths diſtinguiſh the common kinds of iron into two varieties, of which however there are many degrees. To theſe two varieties they give the names of red-ſhort iron and cold-ſhort iron. The red-ſhort is tough and flexible when cold, and works very well when ſtrongly heated, but if under-heated, it is brittle under the hammer; and as there are many varieties, the ſmiths make trials at firſt to learn how the iron is beſt wrought. The cold-ſhort iron, if cooled ſlowly after being heated, proves quite brittle while cold, eſpecially thick bars of it, and acquires flexibility by being plunged red hot into cold water, but is always deficient in it. In its brittle ſtate it breaks ſo as to ſhew facets or plates remarkably large in the ſurfaces of the fracture.

Profeſſor Bergmann made a great number of experiments to learn the cauſes of theſe different qualities of iron, and thought he had diſcovered the cauſe of cold-ſhortneſs, aſcribing it to the preſence of a metal which he called *ſiderum*: But this has been found to be a miſtake. Mayer ſhewed that it is a phoſphat of iron. Mr. Cort's proceſs removes or prevents this bad quality.

When a piece of tough hammered iron is broken by bending, it is found to be fibrous; but if the ſame piece be kept red hot for ſome time, and again broken, the fibrous appearance is almoſt gone. It

would ſeem that it gets it by the action of the hammer, and that iron conſiſts of malleable infuſible ſtuff, mixed with a remainder of fuſible iron. Such a maſs, when heated red hot, muſt work under the hammer, like a paſte in kneading, the fluid part being ſqueezed along between the ductile parts like ſo much greaſe. Perhaps this is the ſource of that ſhining or glowing ſkin which it gets in a welding heat, which enables two pieces to be ſtruck together by the force of blows.

I have now deſcribed the progreſs of iron from the ore to that ſtate of this metal which appears to be the pureſt and moſt perfect ſtate of it, and in which it is called tough iron, or bar iron. I muſt, in the next place, give ſome account of STEEL, which is iron in a different ſtate, and poſſeſſed of properties by which it is much better adapted to ſerve ſome of our purpoſes than tough iron is.

Steel is refined iron, intimately combined with a ſmall quantity of pure carbonaceous matter, or the carbon of the French chemiſts.

Slender bars of iron are put into a crucible, and covered with charcoal duſt rammed cloſe round them. The crucible is luted, and ſet in a furnace, where it is expoſed to a ſtrong red heat for ſome hours. When the iron is taken out, its ſurface is frequently found rough and bliſtered: This I believe is owing to the puſhing the operation a little too far. It is now converted into ſteel, and conſiderably increaſed in weight.

At Newcaſtle, and other places in England, they have furnaces for this purpoſe, in which large quantities are made. Theſe have the form of a large oven or arch, terminating in a vent at the top. The floor of this oven is flat and level. Immediately under the middle of this floor there is a long arched fire-place with grates, which runs quite acroſs from the one ſide to the other, ſo as to have two doors for putting in fuel from the outſide of the building. A number of vents or flues paſs from the fire-place to different parts of the floor of the oven, and throw up their flame into it, ſo as to heat all parts of it equally. In the oven itſelf there are two large and long caſes,

or boxes, built of a good fire-ſtone, and in theſe boxes the bars of iron are regularly ſtratified with charcoal duſt, ten or twelve tons of iron at once, and all is covered with bed-ſand. The heat is continued five or ſix days and nights without intermiſſion. And it requires as long a time for the furnace to cool again, before the ſteel can be taken out, and the boxes filled with freſh bars of iron.

This proceſs is a cementation, and the carbonaceous matter muſt be introduced into the iron in the form of heavy inflammable air. You muſt recollect the experiment of Mr. Morveau, in which he expoſed a diamond to intenſe heat, ſhut up in a ſmall cavity in tough iron. The diamond vaniſhed, and the iron around it was converted into ſteel. Theſe facts ſhew very plainly what happens. The charcoal, or carbon in ſubſtance, combines with the metal.

Accordingly, a chemical analyſis of ſteel ſhews this completely, by giving us the carbon again in ſome other combination, as will appear in a variety of ways. It appears by the reſults of its expoſure to great heats. It is gradually deprived of its qualities of ſteel by long continued red heat, and it emits carbonaceous matter, if not carbonic acid. A fine ſteel wire burns with amazing brilliancy in vital air, and produces both fixed air and inflammable air. This carbonaceous matter is diſcoverable in ſteel by the action of acids, particularly aquafortis. When ſteel is diſſolved in an acid we obtain much more plumbago from it than from the worſt kinds of tough iron, although not ſo much as from the grey caſt iron. If this experiment be performed with ſulphuric or muriatic acids, the difference is not ſo remarkable, but not leſs real. In theſe acids, the ſolution proceeds chiefly, or primarily, from the decompoſition of the water, and inflammable or pure hydrogenous gas is produced. This combines with part of the carbon in its naſcent ſtate, and compoſes the heavy inflammable air, which is really obtained in the ſolution of ſteel in ſulphuric acid, whereas pure tough iron gives us hydrogenous gas.

With aquafortis, the produce of plumbago is much more conſider-

able, when the proceſs is carefully managed. The nature of it is alſo more diſtinctly ſeen; and I am perſuaded that iron conſtitutes an ingredient of it, and that the French chemiſts are in the right when they call it a *carburet of iron*, though others ſay that the iron exiſts in it only accidentally. In the trials I have made, its quantity or proportion is too conſtant to be accidental.

Steel, therefore, appears to be pure iron combined with inflammable matter. By pure iron, I mean the metal completely reduced, that is, cleared of all oxygen, and of all earthy and combuſtible matter; in which reſpect it differs from caſt iron, which undoubtedly contains much earthy matter, united with an oxyd of iron in the form of glaſs, which is entangled in the pores, and cannot be ſqueezed out without a vaſt deal of hammering and labour. The caſt iron reſembles the ſteel in this, that, like it, it contains much inflammable matter, which it got from the fuel, and which remains defended from the action of the air by the very fluidity which it occaſions, and which is expelled only by ſtirring, and preſenting a great ſurface for a long time to the action of the air.

This notion is confirmed by the fact that a ſlender rod of iron, plunged into white or grey caſt iron in fuſion, is converted into ſteel *.

The qualities of ſteel, by which it differs from iron, are,

1. It is more fuſible. Tough iron cannot be melted in the moſt violent fires of common furnaces. It only becomes very ſoft, but never fluid. But ſteel can be melted perfectly in crucibles, if expoſed to the moſt violent heats of common furnaces.

2. In its ſolid ſtate, ſteel is more rigid and hard than iron, nor can it be ſo much ſoftened by heat, without loſing its tenacity and flying in pieces under the hammer. It requires therefore more care and attention to forge it well than to forge iron.

* Should not finery cinder, and all pure oxyds of iron, when reduced by charcoal and proper fluxes, in the nice experiments of the laboratory, be ſteel, and not iron? Are they always ſo? I think not. EDITOR.

3. Steel is much more readily broken by bending it than tough iron. It does not bear to be ſo much bent backwards and forwards. When a bar of it is broken, the ſurface of the fracture is quite different from that of iron. A bar of tough iron ſhews by its fracture that it is compoſed of fibres, the ſurface of the fracture being very rough, with the ragged ends of them. But ſteel, when broken, ſhews that it is compoſed of very ſmall grains, of a plated ſtructure; and preſents a whitiſh grey ſurface, much more plain than that of the broken iron.

The moſt uſeful qualities by which ſteel excels iron are the ſtrong coheſion of its parts*, and the extraordinary hardneſs it acquires when made red hot, and very ſuddenly cooled. It is thus made ſo hard as not only to cut iron with eaſe, but ſteel itſelf in its ſofter ſtate.

This exceſſive hardneſs is attended with perfect rigidity and inflexibility, which makes ſuch hard ſteel in ſome meaſure brittle. Files, which are hardened to this degree, can be broken by a fall. But the artiſts temper this hardneſs more or leſs, to fit the ſteel for different purpoſes.

This is done by heating the hard ſteel again. If its ſurface be made clean by grinding or poliſhing, then, when it is heated again, it will acquire a ſtraw colour, which will gradually proceed to a full gold colour, with ruddy purple ſtreaks, which afterwards become full purple, violet, and deep blue. Theſe colours direct the artiſt in what ſtate he ſhall arreſt the temper, by dipping the ſteel into water or greaſe. The firſt appearance of yellow fits it for the edges of chizels and punches, which are to be employed upon iron itſelf; the full gold colour, or the beginning of purple, fits it for chizels which are to be employed on the ſofter metals; a little more of the purple fits it for common edge tools; and the violet or blue fits it for watch ſprings. When clouds of a dingy yellow are appearing among this blue, it is becoming too ſoft.

* A ſteel wire of one-tenth of an inch in diameter, will juſt break when loaded with 900 pounds, if properly tempered, and more than 700, if ſoft. EDITOR.

It would be a very deſirable thing to combine this extreme hardneſs of ſteel with the toughneſs and tenacity of iron. The only way we can do this is by welding them together. It is thus that our edge tools are made. A bit of ſteel is welded to the iron, on that ſide of the plate or bar which is to be worked into an edge.

There is another way, which is peculiarly ſerviceable on particular occaſions. We can convert the ſurface of any piece of iron into ſteel by cementation, which we can ſtop before it penetrate ſo far as to make the whole become ſteel, and brittle. This is called CASE-HARDENING. The piece of work, when very nearly finiſhed, is covered with a paſte made of charcoal or other combuſtible matters. Long experience has produced an univerſal preference of animal charcoals, or rather the crude ſubſtances. Horn or hoofs, chopped hair, bone ſhavings, and ſome other fanciful ingredients are made into a paſte. The iron is covered with it, and the whole wrapped up in clay. This is firſt dried and hardened before the fire, and then put into the forge, and kept of a low red heat for an hour or two. When taken out, it is ſuperficially ſteeled. In this manner are almoſt all the parts of gun locks treated. Beſides the ſuperficial hardneſs acquired by it, it is well known that they have incomparably leſs friction than when only iron; and they are much leſs liable to ruſting.

The extreme hardneſs appears to me to depend on the extrication of latent heat. And the abatement of this hardneſs by the temper ſeems to be produced by the reſtoration of a part of that heat.

With reſpect to the qualities of ſteel in mixture, they are preciſely the ſame as thoſe of iron, except the ſmall differences proceeding from the exceſs of inflammable matter which ſteel contains. It is more fuſible, more inflammable, not quite ſo readily ruſted or diſſolved; and it can be reduced to iron again, by abſtracting, or otherwiſe ſeparating this inflammable matter.

Beſides the ſteel produced from bar iron by cementation, we ſometimes have it directly from the ore. The ſpathoſe ores in Carinthia

afford it at the firſt. The caſt metal from them is melted in a pot. By throwing a little water on it, a plate is congealed on the ſurface, and lifted off; and this is repeated till all is expended. Theſe plates are then melted again, and kept in a melting heat for a long time, which requires a continual increaſe of heat; and they are found to be ſteel. An ore in the iſland of Elba, and ſome ores in Barbary, have the ſame qualities with the German ores now mentioned. We do not well know the various proceſſes, many of which ſeem very fanciful.

The fineſt and beſt kind of ſteel is called *caſt ſteel;* and the proceſs for preparing it was invented in England. All fine inſtruments and razors are now made of it. *(See Note 21. at the end of the Volume.)*

I conclude this article by referring you to Fourcroy, who has treated this important ſubject with the greateſt diſtinctneſs, and a very fair and copious narration of facts, ſo that I think a judicious chemiſt will find himſelf quite independent of all his theories, which ſeem but ill ſupported.

Medicinal Virtues of Iron.

This metal has always been eſteemed as a valuable article of the materia medica; and furniſhes, in its preparations, medicines of great efficacy. There ſeems to be no foundation, however, for the opinion which chemiſts entertained with regard to it, that according as it is differently prepared, it acquires powers over the body of a different, and almoſt oppoſite nature.

Iron itſelf, and moſt of its preparations, taken into the body, has often a very manifeſt conſtringing effect, which is ſtill more remarkable in ſeveral of its preparations, when applied externally, in caſes of hemorrhage from wounds, &c. They act with ſome degree of acrimony and pain, in contracting the veſſels from which the hemorrhage proceeds. They have often had this effect, when given in caſes where it was not practicable, or not eligible, to apply a remedy directly to the part itſelf from which the hemorrhage proceeded; as in dyſentery, hemorrhoids, too profuſe flow of the menſes, lochiæ, &c. Theſe

obſervations firſt eſtabliſhed the character of iron as an aſtringent medicine. But its effects upon other occaſions ſeemed to be of a different kind. Both the metal itſelf in ſubſtance, and all its preparations, were long noted as ſome of the moſt powerful remedies by which the menſtrual evacuation may be reſtored, after it is ſuppreſſed; and for promoting the motion of fluids through the whole body. The ſaline preparations of iron, if exhibited along with a conſiderable quantity of water, increaſe very ſenſibly the evacuations in the form of urine, and of perſpiration; and, if given in a greater doſe, have a quick effect in exciting diſcharge from the guts. On account of theſe effects, the metal was alſo ſuppoſed to be endued with an aperient or deobſtruent virtue, attributed to one of the ingredients in its compoſition, viz. the phlogiſton; while the aſtringent virtue was referred to another,—the earth. And the chemiſts endeavoured, by a variety of proceſſes, to ſeparate them, or obtain ſome medicines poſſeſſed only of the aperient quality, and others only aſtringent. And ſome even imagined that they performed this in ſome degree; ſo that we ſtill find, in ſome diſpenſatories, preparations diſtinguiſhed by the titles of aperient or aſtringent. It is, indeed, certain that ſome of the preparations contain a larger proportion of the inflammable metal than others; but it appears from the conſent of practical phyſicians on the ſubject, that this only renders the medicine more or leſs efficacious,—thoſe containing the greateſt quantity of this ſubtile principle producing their effects more ſenſibly and certainly, but not differing in the manner of their operation from others.

The powers by which iron produces its effects are, in the firſt place, its aſtringency, or conſtricting virtue, a power of bracing the fibres over the whole body, diminiſhing in ſome degree the cavities of the veſſels, and increaſing the force wherewith they compreſs the fluids. Secondly, a powerful ſtimulus, friendly to life. By this it excites or promotes circulation, and all thoſe motions in the body by which the alimentary parts are converted into good fluids, and the fluids preſerv-

ed in a ſound healthy ſtate; and by which all ſecretions, both of recrementitious and uſeful fluids, and all abſorptions, are performed in different parts of the body. By this laſt property, iron differs from lead, which, together with aſtringency, ſhews a power rather of diminiſhing and deadening motion, and therefore is a much more powerful, though dangerous aſtringent. The aſtringent quality of the preparations of iron ſhews itſelf, by the taſte of acerbity, which draws the mouth together, and by Dr. Hale's experiments with Chalybeate water. Their ſtimulating effects become ſenſible, if a large quantity of them be taken: They prove purgative, or even emetic, with a good deal of heat and diſturbance. Theſe effects ſhew, that when applied in conſiderable quantity to the nerves of the ſtomach and guts, they not only ſtimulate theſe, ſo as to produce a conſiderable increaſe of the ſecretions performed in thoſe parts, but alſo excite a motion by which they are expelled. Their ſtimulating effects are likewiſe extremely evident over the whole ſyſtem, when uſed in ſmaller quantity, ſo as not to produce diſturbance in the ſtomach and guts. This ſtimulus is ſhewn by the warmth it diffuſes over the whole body of the perſon who needs it, by giving a freſher colour to the ſkin, by the vigour and alacrity with which it inſpires, in conſequence of exciting a more briſk circulation. Phyſicians have doubted whether this action of iron proceeded from its entering the lacteals, and being mixed with the blood; becauſe they obſerved that perſons put under a courſe of ſuch medicines very evidently void a conſiderable quantity of ochre, or calx, in the fæces. And, indeed, it is certain that the ſtimulus and conſtriction with which it affects the ſtomach muſt have immediate effect on the whole ſyſtem, on account of the remarkable ſympathy daily obſerved between the nerves of the ſtomach and thoſe of every other part almoſt of the body. But it is very probable too, that ſome part enters the blood, becauſe, although ſalts obtained from iron readily depoſit a conſiderable quantity of ochre, it is not found that they can be entirely reſolved in this manner. But in what-

ever way it act, it is certain that a very quick change is wrought in the blood and circulation. The belly is, indeed, often bound in ſome meaſure, and the coſtiveneſs is produced, probably by quick abſorption of the thinner parts of the food; but it is eaſily obviated by a ſmall doſe of rhubarb.

Upon account of theſe two qualities, iron and its preparations are among the moſt powerful remedies in weakneſs and laxity of the ſolids, and in watery diſpoſition and poverty of the fluids, together with all diſeaſes depending upon ſuch a ſtate of the body—ſuch as diſpoſition to dropſy, and anaſarca, or watery ſwelling, fluor albus, gleet, hyſterical and hypochondrical diſeaſes, indigeſtion, diabetes, diarrhœa, and the too copious flow of the menſtrual flux, when theſe proceed ſimply from a weakneſs and relaxation of the ſolids. In the chloroſis, it not only removes the languor, but reſtores the proper flow of the menſes, by the ſtoppage of which this diſeaſe is either produced, or very much increaſed.

In autumnal intermittent fevers, when obſtinate, and the body much waſted, it prepares for bark.

The preparations from iron are not adviſeable, if the humours are conſiderably acrid, or when there are appearances of a putrid tendency. In ſuch caſes the nervous ſyſtem is generally too irritable.

When the veſſels are very full, iron medicines are hazardous, for the ſame reaſons; and indeed it is always a proper precaution to take off ſome blood before a courſe of them.

In perſons of ſtrong and rigid fibres, and thoſe ſubject to violent cramps, theſe medicines have often left ſenſible effects, in a diſpoſition to theſe complaints.

In ulcerated lungs, and old and obſtinate obſtructions of the viſcera, they are ſerviceable, and it is always proper to give them in ſmall doſes, and continue them ſome time.

The moſt certain preparations are, limatura ferri,—ferrum ſaccharatum,—crocus martis aperie s,—crocusmartis aſtri n, ens,—tincturæ martis,—ſal martis,—flores martiales.

GENUS IV.—MERCURY.

MERCURY is diſtinguiſhed by being always fluid, and being by far the moſt volatile of all metallic ſubſtances. And theſe two qualities have laid ſome chemiſts under difficulties and doubts with reſpect to its proper rank among the metals. They made it a queſtion whether it ought to be called a metal, or ſemi-metal; and many have thought it could not properly come under either one or other denomination. But there is no reaſon to doubt that it is a metal. All the metals are fuſible, or capable of fluidity, and volatile too, as well as it, and it differs from them, only in being more fuſible and volatile than any of them. We know now that it becomes ſolid, and proves very malleable, when cooled to a ſufficient degree, viz. —40° of Fahrenheit's thermometer.

Chemiſts have given much of their attention to mercury, partly with alchemical views, and partly with a view to medicine. The alchemiſts probably expected ſucceſs in their attempts upon it, on account of its great weight, by which it approaches more nearly to gold than the other metals then known,—its ſpecific gravity being 13568 *. And it became very much the object of pharmaceutical chemiſtry, ſoon after it was diſcovered to be a ſpecific for the venereal diſeaſe, and before the beſt manner of applying it in the cure of that diſtemper was well underſtood. Its action on the human body, as it was employed at firſt, was attended with great inconveniences, and permanent injury, and even fatal conſequences. It was thrown in haſtily, and in great quantities, until it brought on a plentiful ſalivation, which was ſo violent, that it kept the patient in mi-

* A cubic foot weighs 13,568 ounces avoirdupois, or 848 pounds.

EDITOR.

ſery ſo long as it laſted. And moreover, the mercury, when employed in this manner, is liable to ſtimulate ſome other ſecretary organs beſide the ſalivary glands, with a degree of violence that is not without danger.

The chemiſts imagined that theſe troubleſome effects depended upon ſome noxious corroſive principle in the compoſition of mercury, and therefore tried innumerable proceſſes with it, and changed it into a thouſand forms, to ſeparate, if poſſible, the noxious corroſive parts of it, and increaſe the medicinal powers of the reſt. But the opinion upon which they proceeded appears to have been erroneous; and their labour has been in a great meaſure loſt. Many of their preparations, it is true, are uſeful, and applicable to particular purpoſes for which crude mercury is not adapted; and in ſeveral, they reduced it to the moſt efficacious forms; but in none of them have they taken away its power to produce noxious effects. Theſe are only to be avoided by attention and ſkill in the management of it. When employed in the venereal diſeaſe, it never ſhould be thrown in ſo haſtily as to produce a great ſalivation, by which it will run out of the body again as faſt as it is thrown in. We generally give it in ſuch quantities as to bring on a ſlight ſpitting and affection of the gums; for unleſs this ſign of its action can be perceived, we cannot be ſure that its powers are employed; but it never ſhould be made to act with greater violence. And we muſt be careful that it do not excite other evacuations, and run off by them. We muſt be alſo careful to remove or obviate any diſpoſition to inflammation, which may appear by inflammation actually preſent, or by a fullneſs and hardneſs of the pulſe. The firſt impreſſion of the mercury always increaſes the inflammatory diſpoſition, and unfortunate conſequences often follow. The fortunate uſe and effects of mercury, therefore, depend more on the judicious management of it, than on its having been prepared by elaborate proceſſes: At leaſt, if we conſult experienced practitioners, who know more of diſeaſes than of chemiſtry, the moſt will give it as

their opinion, that the plain pill or ointment are equal, for the cure of the venereal diſeaſe, to all other preparations. It is neceſſary, however, to make it undergo at leaſt the proceſs of *trituration*, and that with the greateſt care, and in the moſt perfect manner, that the parts of it may be divided and attenuated, and that very ſubtilely, to make it act certainly upon the human body. When thrown in undivided, it runs through the inteſtines, and produces no effect, or very little, and very uncertain. It was the faſhion about fifty years ago to take mercury in this manner, from an opinion that it had extraordinary good effects, by virtue of a ſpirit, or effluvium, that was ſuppoſed to be extracted from it by the inteſtines, though no part of the mercury itſelf, or none of its groſſer parts, entered the blood. It happened, however, in ſome caſes, that even the crude mercury, thus given, brought on a ſalivation; but from its having produced this effect in a few caſes only, there is reaſon to believe that it had lodged in the inteſtines, and was divided by their motion.

When we deſire to give it with certainty of its producing an effect, and of the effect being proportional to the quantity thrown in, we muſt take care that it be prepared at leaſt by the moſt careful diviſion or ſeparation of its particles from one another. One way of doing this is, by rubbing it long and patiently with viſcid and other ſubſtances, which, by interpoſing themſelves between the divided parts, hinder them from readily joining again. The ſubſtances ſuitable to this intention, are axunge, turpentine, and other balſams; mucilages, that is, mixtures of gummy ſubſtances with water; viſcid ſweets, as honey; even earthy powders ſometimes, and water. Boerhaave firſt produced a black powder from mercury by agitating it in water; and Dr. Prieſtley has made many experiments upon this black powder and its production, and has diſcovered a number of curious particulars relating to it. You will ſee them deſcribed in the volumes which he has publiſhed, to which I refer you.

In whatever way mercury is thus divided, it acquires a ſmall de-

gree of ſolubility in the animal humours, and affects the tongue with a ſenſation of a particular nauſeous taſte, which ſhews that ſome of it is diſſolved by the ſaliva. This power in our fluids to diſſolve mercury probably depends upon the ammoniacal ſalt they contain, for common ſal ammoniac plainly acts upon mercury when rubbed with it.

But it is alſo believed by many, that water, unaſſiſted with any other matter, has ſome power to diſſolve it, or to receive from it ſome medicinal efficacy. Gaubius, the French phyſicians, and many others, aver, that when it is boiled in water, it gives to the water the power of killing worms in the inteſtines of animals. Such water has been recommended by many as an effectual and ſafe anthelmintic; and this power it can only derive from ſome ſmall part of the mercury diſſolved in it, though, if there is any, it muſt be exceeding ſmall, as the mercury does not ſuffer a perceptible loſs. The water certainly acquires what is called the metallic taſte, not ſenſible at firſt, but ſufficiently ſo in a few hours, and for a long while after.

When mercury is expoſed to the action of heat, it ſoon begins to evaporate and boil like water. This happens when the mercury is heated to about 600° of Fahrenheit's thermometer *.

The vapour of it, when mixed with air, does not immediately calcine, as the vapour of ſome of the other volatile metals does. If immediately condenſed, it returns again to the form of mercury. And this metal may be diſtilled in a retort, without ſuffering any material change. We can therefore purify it by this proceſs from admixture with other metals, moſt of which it is capable of diſſolving or mix-

* It evaporates in temperatures far below this, when the preſſure of the atmoſphere is removed. If a well filled barometer be kept near a window in a warm room, the part of the tube above the column of mercury becomes dim within, on the ſide next the window. When this is viewed through a magnifying glaſs, it will be ſeen owing to ſmall ſpherical drops of mercury, which the coolneſs of this ſide of the tube has condenſed. If the barometer be inclined, ſo as to make the mercury reach the top of the tube, it will lick them all up, and the tube becomes quite clear.

EDITOR.

ing with. And it happens to be mixed with them ſometimes, either by accident or by deſign, in different operations in which it is employed. When thus mixed, it is called foul or impure mercury. The ſigns of this foulneſs are,

1*ſt*, A flat ſurface in the phial, not convex like that of pure quickſilver, the convexity of which ſhews that it has more coheſive attraction than the impure.

2*dly*, The formation of a pellicle on its ſurface, in conſequence of which a ſort of wrinkles are formed on it in moving it gently. This pellicle, adhering to the ſurface of the veſſel, leaves a train behind the mercury, when it is made to run from one part of the glaſs to another.

3*dly*, The formation of a black powder upon the ſurface of mercury, when it is ſhaken in a phial with good or reſpirable air, and ſtill more quickly with vital air.

It ſometimes has the appearance of a pellicle on its ſurface from duſt or greaſineſs, or dampneſs adhering to it. In this caſe, ſtraining it through thick linen or leather, or paſſing it through a paper cone, will make it clean. But if it becomes foul again, there is reaſon to conclude, that other metals are the cauſe of its foulneſs, and it muſt be made clean. There are various methods for doing this. Simple agitation, in contact with atmoſpheric air, will produce this effect. It is a general fact, that all mixtures of metals attract oxygen more ſtrongly than the metals when ſeparate. This is remarkably the caſe with mercury. Agitation with air quickly produces a black powder, which, when ſeparated by filtration and expreſſion, is found to be chiefly a calx of the other metals; and we can obtain the mercury perfectly pure by this proceſs. But ſome of the mercury is entangled in the powder, and ſome is really oxydated: It is not, therefore, the beſt proceſs for purifying mercury; and it is but a lately diſcovered one. The uſual proceſs has been by diſtillation. Iron filings are added, and with good effect. Their uſefulneſs is commonly imputed to their

attraction for the metallic impurities. But lead is the moſt common impurity; and iron has no attraction for it. Others ſuppoſe that they ſerve only to prevent any drops of the boiling mercury from ſtarting over into the neck of the retort. But though ſand anſwers this purpoſe, it has not the effect of iron, which gives the mercury a remarkable degree of brightneſs and mobility.

Iron calcines moſt eaſily and rapidly, and muſt therefore be a powerful opponent to the calcination or oxydation of the mercury, quickly abſorbing any vital air that may be in the apparatus. The greaſy matter too, which is in all filings of iron, contributes in the ſame manner to prevent the oxydation of the mercury. I have very frequently perceived a ſtrong ſmell of volatile alkali in the veſſels in which mercury has been diſtilled with iron filings. I apprehend that this is formed by the union of atmoſpherical azote with hydrogen diſengaged by the iron from moiſture contained in the veſſel and materials.

Though this metal does not calcine very perceptibly, when only changed into vapour to be immediately condenſed again, it is not incapable of being calcined.

There is a proceſs deſcribed in chemical books, by which it is changed into calx or oxyd by the action of air and heat. The heat applied muſt be ſuch as will keep the mercury conſtantly circulating; and it muſt be applied without interruption for ſeveral months, to produce a moderate quantity of calx. This is performed in a matraſs of a low flat ſhape, with a long neck, and a capillary opening at the extremity. Some chemiſts alſo recommend a ſmall opening below. The mercury is kept continually, though gently boiling; and after a long time, a red calx or oxyd appears on its ſurface, which continues to increaſe: It is called *mercurius calcinatus*, *vel precipitatus*, *per ſe*. The combination with vital in the formation of this precipitate, may be very plainly ſeen by tying an inflated bladder to the top of the matraſs. It will gradually collapſe, and in a ſhort time be quite flaccid. Chaptal, a great practical chemiſt, ſays that it abſorbs nearly eight

per cent. It is ſaid that a ſmall portion of gold greatly expedites the calcination of the mercury.

The calx is much leſs volatile than mercury in its metallic form, and even endures the firſt beginning of ignition, and melts into a beautiful glaſs; but if the heat be increaſed above this degree, the calx is gradually converted into vapour, and at the ſame time returns again to the form of quickſilver; for theſe vapours, when condenſed, afford quickſilver inſtead of calx. While this reduction of it is performed, a great quantity of very pure vital air is obtained from it, each ounce of oxyd yielding about fifty cubic inches. This method for producing pure vital air was firſt diſcovered by Dr. Prieſtley and Dr. Scheele. But it is to Mr. Lavoiſier that we are chiefly indebted for the diſtinct account of this proceſs, and for the ingenious and moſt important inferences which may be made from it. I may venture to ſtate this as the moſt intereſting fact in modern chemiſtry. Mr. Lavoiſier ſaw it in all its importance, made a multitude of experiments on it, which are models of judicious procedure, and evince the ſoundeſt judgment, as well as the greateſt ingenuity.

According to him, this calx conſiſts of mercury and oxygen, in the proportion of twenty-eight to one nearly. This oxygen was imbibed from the air in the veſſel. It appears from Dr. Prieſtley's experiments with mercury, agitated in a phial, that the production of the black powder (which is alſo a leſs perfect calx) is always accompanied by the abſorption of the vital air of the atmoſphere. For Dr. Prieſtley found that the air of the phial was phlogiſticated, that is, by what we know now of the matter, the azote was left alone. And when he afterwards agitated the mercury with vital air, he found it not phlogiſticated, but conſumed or abſorbed. Lavoiſier obſerves that this abſorption goes on during the tedious proceſs juſt now deſcribed for the calcination of mercury; for the calcination ſoon ſtops if the capillary tube be ſhut up. In this caſe, if we puſh the heat a little farther, part of the calx is reduced again; and if we go too far,

we burſt the veſſel. When theſe facts are compared with the extrication of vital air in the reduction of the *mercurius calcinatus per ſe*, the inevitable concluſion ſeems to be, that the union between mercury and oxygen is ſo ſlight, that a very low temperature is ſufficient for ſeparating them. Mr. Lavoiſier varied this experiment in many ways that lead to the ſame concluſion.

No ſubſtance has been ſo much tortured by the chemiſts as this metal. It has been united or mixed with almoſt every ſubſtance in nature, and it appears to form ſome combination with them all; for by ſimple trituration with any ſubſtance whatever, even dry ſand, the mercury loſes its metallic luſtre and its fluidity, and becomes black; at the ſame time it becomes very ſenſibly ſapid, and affects the nerves of the ſtomach and the ſecretory organs. But this is owing to its diviſibility, and its diſpoſition to oxydate when preſented to the air in ſuch an extended ſurface.

All the more powerful chemical agents combine with it very readily; and the combination affords a great many remarkable and inſtructive appearances. I ſhall firſt conſider its relation to the acids.—

1*ſt*, The vitriolic acid has no action in the cold, not even though in its ſtrongeſt ſtate. If we dilute it with water, it cannot act on mercury, even though aſſiſted by heat. In order to combine the acid with this metal, we muſt take the acid in its ſtrongeſt ſtate, and employ the aſſiſtance of heat to make it act. It will then diſſolve half or two thirds of its weight.

When the acid becomes near boiling hot, it begins to diſſolve the mercury with efferveſcence. This efferveſcence is occaſioned by the change of a part of the acid into ſulphurous acid, which change always happens to a part of this acid, when made to act on metals in its ſtrong ſtate, without addition of water. The diſſolving metal, not having water to act upon, and to ſupply it with oxygen, attracts a part of the oxygen of the acid. This, in conſequence, is decompoſed, and returns more nearly to the ſtate of ſulphur from which it was originally

produced. And there are even many examples of the change of a part of this acid into perfect inflammable ſulphur, when it is made to act in its ſtrong ſtate on ſome of the metals. On account of the change which a part of the acid undergoes in this manner, we muſt uſe more of it than what actually remains afterwards combined with the oxyd of the mercury. In proportion as the *oxydated metal* and acid unite, they form a ſaline compound of difficult ſolubility, which is accumulated around the mercury in form of a white matter; and if we have uſed a proper quantity of ſulphuric acid, the whole is converted into a white ſaline maſs, whoſe regular cryſtals are four-ſided columns, terminated at each end by pointed pyramids. Seldom, however, does it attain this complete form.

This is a ſingular ſalt, and preſents an appearance of much importance to be attended to in the metallic ſalts. It ſeems to be a mixture of two very different ſubſtances. For if boiling water be applied, we ſeparate from this maſs a portion having a yellow colour, and almoſt perfectly inſoluble in water, and not containing a particle of ſulphuric acid. Its colour occaſioned its being called *turpethum minerale*; and it was conceived to be a perfect calx of the mercury, like that obtained by the action of heat and air. It is indeed found to be a perfect oxyd, united only with the oxygen which was ſeparated from that part of the acid which eſcaped in the form of ſulphurous acid, that is, deficient in oxygen. This turbith, when urged by ſtrong heat, is decompounded, affording mercury in its metallic form, and vital air.

The other portion ſeparated by the boiling water conſiſts of the oxyd now deſcribed, combined with the acid, and is a real *ſulphat of mercury*. It cryſtallizes in ſlender deliqueſcent needles. Still this ſulphat exhibits nearly the ſame properties with the maſs from which it was ſeparated. For long boiling ſeparates the acid from part of it, and leaves it in the form of a turbith; and I believe the ſame effect will be produced on what has now been ſeparated, and that the whole may

in this way be changed into turbith. When the turbith and water firſt poured on it for waſhing it have boiled together for ſome time, an efferveſcence takes place, and ſome elaſtic matter eſcapes, which I have not examined. In theſe proceſſes, it is plain to obſervation that the firſt boiling water ſeparates the greateſt part of the acid; but if the mixture be allowed to cool, the calx reſumes a conſiderable portion of it, and the paleneſs of colour ſhews that the turbith is not nearly perfect. The water containing the acidulous ſulphat ſhould therefore be poured off immediately.

With reſpect to the other part of the ſaline maſs, which has been cleared of the mercurial oxyd, and is a true ſulphat of mercury, I muſt obſerve, that it is a very acrid mercurial compound, and ſpeedily deſtroys all organized ſubſtances *. It is much leſs volatile than quickſilver; and when urged by a ſtrong heat, it ſublimes without decompoſition. The truth is, that the ingredients differ ſo little in volatility that they ſhould riſe together, and we ſhould not expect any decompoſition. But if the vapours come in contact with the atmoſphere, they ſeem to be completely decompounded, and this in a variety of ways, yielding mercury, cinnabar, ſulphur, and ſulphurous acid, according to circumſtances.

The ſulphat of mercury is decompounded by alkalis. Fixed alkali precipitates the mercury of an orange brown colour, when mild, but more approaching to yellow, when cauſtic. Volatile alkali, in its cauſtic ſtate, will ſcarcely decompoſe the ſulphat; but by the help of

* The various appearances which this ſalt exhibits ariſe from a different proportion of ſulphuric acid which it may contain. In its yellow ſtate, it contains leaſt of all; when white, it contains more. Waſhing the white maſs with boiling water makes it yellow, the water taking off the more ſoluble part. When this is evaporated and ready to cryſtallize, or would cryſtallize by cooling, the addition of a very minute quantity of acid prevents the precipitation till farther evaporated,—ſhewing plainly that the greater ſolubility ariſes from an exceſs of acid. Conſult Fourcroy for a very diſtinct account of all theſe ſtates.

EDITOR.

a double elective attraction, it does it very readily, when united with excefs either to carbonic or muriatic acid. Lime-water alfo precipitates the mercury, of a brown or yellow colour, according as little or much lime-water has been employed.

I obferve that fome chemifts affert, that by repeated diftillation of fulphuric acid from mercury, in this procefs, the mafs becomes more and more fixed, and melts into a blood red fluid before it evaporates. (*See Cornette Mem. Acad.* 1799.) I have not obferved this: Nor has Mr. Bayen, who has made a great many very judicious and intereffing experiments on this fubject.

The nitric acid diffolves mercury more quickly and readily than any other acid does. The moft convenient ftrength of the acid is when diluted with about an equal weight of water; in which diluted ftate it is called aquafortis. It is properly diluted when an ounce of it can diffolve an ounce of mercury.

This folution exhibits no remarkable appearance at firft. Generally the metal lies quiet for fome little time at the bottom; and all that we obferve is a green colour in that part only of the folution, where it is in contact with the mercury. This colour gradually fpreads farther up, and fmall bubbles appear rifing from the mercury, but are abforbed as they afcend, till the green colour produced by them at laft reaches the furface. They then fly off in the ufual form of red fumes. If water be carefully added to the mixture, before the green colour reach the furface, the bubbles will rife a little way in the water before they are abforbed, and they tinge it green, and promote the mixture of the acid liquor with the water above it. By very careful management of the procefs in this way, Bergmann has fometimes obtained a complete folution, without any efcape of red fumes. This, however, is a very rare cafe, and the folution has rare properties. Had the water not been added, and had the fumes broken out, and a complete folution been obtained, the addition of fo much water to the folution would have caufed a great portion of the mer-

curial nitrate to fall down; but the ſolution obtained without effervescence will bear any dilution with water.

The more common phenomenon of the proceſs is a ſpeedy formation of the ruddy effervescence. The riſe of the bubbles from the mercury is accompanied by a conſiderable extrication or formation of heat; and when the ſolution is carefully obſerved, the bubbles are plainly ſeen to form in all parts of the green liquor. In ſhort, the acid is changing from nitric to nitrous, and an elaſtic matter breaks out that is deficient in oxygen. The ſolution grows very warm, and the fumes become very copious, and blood red. Hence we muſt conclude, in conformity to the numerous facts already mentioned on different occaſions, that the metal is now acting on the acid, and decompounding either the whole, or only a part of it, by abſtracting from it a portion of its oxygen.

When thoſe fumes, inſtead of being allowed to eſcape into the atmoſphere, and mix intimately with it, are made to paſs through a narrow glaſs veſſel, the ruddy colour ſoon diſappears in the tube, and the expelled gas becomes quite tranſparent there, and almoſt colourleſs. It may be collected in the ſame way that we have employed for other gaſes, by making it paſs into inverted jars filled with water, and ſtanding in a ciſtern of that fluid. Taking this method, we find that all the acid qualities are gone. The gas has ſcarcely any taſte. It has very little attraction for water. Diſtilled water diſſolves about one-eighth of its bulk, but retains it ſo weakly that a ſhort expoſure to the air diſſipates it completely.

This colourleſs, elaſtic, aëreal matter, was firſt deſcribed by Dr. Prieſtley, who called it *nitrous air*. The French call it *nitrous gas*. The moſt common name of it in England, however, is ſtill *nitrous air*. It is now well known to be a portion of the acid of nitre, diſguiſed or changed by the loſs of a great quantity of its oxygen, which the diſſolving quickſilver has abſtracted from it. One proof of this is, that if we ſeparate the quickſilver from the acid, either by precipitat-

ing it with a pure alkali, or by the action of heat alone, we get, by either way, an oxyd of the mercury, which is not unlike to the oxyd obtained by the action of air and heat. And like that oxyd, it yields a large quantity of pure vital air, when heated red hot in a retort, the mercury at the ſame time reſuming its metallic form. We have another proof, by mixing this elaſtic fluid with atmoſpherical air, or vital air, which has much more effect. Either of them, by ſupplying oxygen, changes the nitrous air into nitrous acid, which ſhews itſelf in red vapours, and is immediately attracted and abſorbed by the water. Much leſs of the vital than of the atmoſpherical air is ſufficient to produce this change on the nitrous air; and it is evident, from other experiments, that the atmoſpherical air produces its effect only by virtue of the vital air which it contains.

When theſe red vapours are formed, a conſiderable heat is produced in the glaſs. This heat is ſuppoſed by the French chemiſts to be a part of the heat, or matter of heat, or calorique, which was contained in a latent ſtate in the compoſition of the two elaſtic fluids. *(See Note 22. at the end of the Volume.)*

By means of this nitrous air, Dr. Prieſtley very ingeniouſly contrived to diſtinguiſh wholeſome or reſpirable air from the different kinds of tainted or noxious air, and endeavoured to meaſure the *different degrees of wholeſomeneſs* or purity in common atmoſpheric air. His method of doing this is deſcribed in the volumes he has publiſhed; and his apparatus is ſuch as enables him to ſubject a ſmall quantity of air to this ſort of trial or teſt, as he calls it. The principle of the method is briefly this. Nitrous air is the vapour of nitric acid deprived of part of its oxygen. If, therefore, a cubic inch of it be mixed with as much vital air as will make up the deficiency, they will unite and form nitric or nitrous acid, miſcible with water. If, therefore, a cubic inch of this gas be thrown up into a jar inverted over water, and containing an air conſiſting of as much vital air as is required by this nitrous air, and three cubic inches of any other

gas immiſcible with water, whatever may be the bulk of this compound air, it will be reduced to the bulk of three inches. If, therefore, nitrous air be very uniform in its compoſition, a ſingle experiment will inform us what bulk of vital air it will unite, and diſappear with, by abſorption in the water. Therefore, throwing up nitrous air, till there ceaſes to be a diminution, will inform us how much vital air is in the mixture. Nay, as this requires time, and certain complicated precautions, a ſeries of proper experiments will teach us the proportion of vital air, by means of the contraction occaſioned by mixing a given meaſure of nitrous air with any quantity of compound air; and we may proceed on this principle, that 100 parts of nitrous air abſorb 48 of pure vital air, ſo that both diſappear.

Dr. Prieſtley's apparatus conſiſts of a tube, in which the bulk of the mixed airs is meaſured. It is about three feet long, and one-third of an inch wide. In examining atmoſpherical air, or air like it, he mixes two ounce meaſures of ſuch air with one of nitrous air in a ſmall jar; and ſoon after throws up the mixture into the long tube, the cavity of which is divided into ounce meaſures, and each of theſe into a hundred parts by a ſcale, and he expreſſes the reſult of the trial, by telling the number of theſe parts which the mixture fills after the abſorption is over. The beſt air, therefore, gives the ſmalleſt number.

In trying air better than atmoſpherical, he adds to one meaſure of ſuch air two meaſures of nitrous air, which quantity of the nitrous air is enough for the pureſt vital air.

Other authors have endeavoured to make improvements in the manner of employing nitrous air for this purpoſe. The Abbe Fontana has ſtudied this point with particular care, and has deſcribed his *apparatus*, or the *eudiometer*, as it was firſt called by Landriani, in which there are many neat contrivances. Mr. Cavendiſh alſo has given ſome accurate and ſkilful remarks in the 73d volume of the Philoſophical Tranſactions. And Dr. Ingenhouſz has made ſome

improvements in the manner of uſing the apparatus. But the contrivance which appears to me the moſt ſimple and convenient, as well as the moſt exact, is that of Mr. Sauſſure.

He uſes a phial, which he calls the *receiver*, containing about five and a half ounces of water. Its diameter and height are nearly equal, and it has a ground ſtopper well fitted. He has another ſmall phial, called the *meaſure*, which contains ſomewhat leſs than one-third of the former. He has alſo a ſmall funnel, and a ſmall exact balance. (*Sauſſure Voyage dans les Alpes, p.* 514.)

Having prepared the requiſite quantity of nitrous air on the ſpot, he proceeds as follows: 1*ſt*, Having filled the recipient with water, and holding it under water in the bucket, he introduces into it two meaſures of atmoſpheric air, and one meaſure of nitrous air. He then ſhuts the recipient with its ſtopper, and ſhakes it under water, opening it now and then to let in the water. This ſhaking and opening is performed juſt three times in every experiment, in order that all may be perfectly ſimilar. 2*d*, The recipient is now ſtopped cloſe, and its outſide is wiped quite dry. It is then weighed, and its weight compared with what it would be if three meaſures of common air had been admitted. The difference in his apparatus amounted commonly to one ounce ſix drachms and forty grains. N. B. His meaſure contained one ounce ſix drachms twelve grains of water. Suppoſing, therefore, that two parts of nitrous air combine with, or are decompounded by one of oxygenous gas, the quantity of this gas in common air is, by the above reſult, juſt one-fifth of the whole common air, or 340 in 1704: More exactly, it is 22 *per cent.* By ſuch experiments he learned that the air of the valleys among the Alps, and at Geneva, is better than that on the tops of high mountains by about nine grain meaſures of oxygenous gas in the above two meaſures. This is probably owing to the action of plants during ſun-ſhine.

I am perſuaded that this apparatus is more uſeful than the expenſive and fragile eudiometers conſiſting of tubes and ſtop-cocks. But when

I reflect on the unavoidable differences in the proportions of the ingredients of nitrous air extemporaneouſly prepared, and on the different propenſities of ordinary water to abſorb or emit elaſtic fluids, I cannot think that theſe eudiometrical experiments are a proper foundation for any accurate judgment of the ſalubrity or unwholeſomeneſs of airs. And I ſhould be ſorry to ſee much dependance had on them. I have always conſidered them as too delicate for the hand of any perſon but a judicious chemiſt, perfectly at leiſure. The odds of 10 or 20 grains in 1740, is an error from which it would be difficult to ſecure ourſelves. Yet even this is a very great part of the greateſt differences that have been obſerved. It is alſo very inaccurate to conſider this experiment as a teſt of the wholeſomeneſs of air, and to call the inſtrument a eudiometer. Chemically ſpeaking, it only meaſures the quantity of oxygenous gas contained in every air. We know very well, that the commixture of ſome exhalations, particularly of flowers of the lily kind, in a quantity too ſmall to be perceived by ſuch a teſt, gives the air a power of affecting ſome of our organs in a way which, though not immediately deadly, is yet extremely prejudicial to good health.

Accordingly, the experiments made to examine the goodneſs of air by employing nitrous air, do not always agree exactly together, even though made with the ſame airs and materials, and the ſame apparatus. And when we wiſh to be exact, it is neceſſary to repeat them ſeveral times, and to take a medium of the reſults. And when we chooſe to compare two portions or ſpecimens of atmoſpheric air with one another, the experiments for this purpoſe ſhould always be made at the ſame time, and in the ſame place, and with the ſame nitrous air recently prepared; experience having ſhewn that nitrous air is ſenſibly different in its quality, as it is prepared at different times, and in different places. This is now underſtood to proceed from the more or leſs violent change which the acid ſuffers when we are preparing the nitrous air. A part of the acid always undergoes the changes you

have ſeen, but a ſmall portion of it is completely decompounded, the whole oxygen being taken from it, and then what remains of this portion is azotic gas, which cannot be brought back to the ſtate of nitric acid by ſimple mixture with reſpirable or vital air. There is only one way by which we can bring it back to the ſtate of nitric acid, or convert it into that acid, that is, by mixing three meaſures of it with ſeven meaſures of vital air, and then promoting the union of the two airs, or their action on one another, by a ſtrong heat, or by repeated flaſhes of electrical fire, in the manner practiſed by Mr. Cavendiſh, in the courſe of thoſe curious and important experiments which I have frequently referred to as the great ſupport of the new chemical doctrines and diſcoveries. Now, when metals are diſſolved in nitric acid, ſome ſmall portion of the acid is, as I ſaid juſt now, ſo totally deprived of oxygen, that it is changed into azotic gas, and this happens more or leſs according to the violence, rapidity, and heat, with which the diſſolution is performed; and therefore the nitrous air which we get, turns out different on different occaſions, by its containing different quantities of azotic gas, and being more or leſs fit for the examination of the wholeſomeneſs of reſpirable air.

By this trial air is judged to be wholeſome, or fit for reſpiration, in proportion to the quantity of nitrous air which it can decompound; and this is known by the diminution of bulk which happens in the mixture of the two airs as confined by water. If there is no diminution of the two airs, the one which was mixed with the nitrous air is totally unfit for the ſupport of animal life, even for a moment; and if there is but little diminution, an animal will die in it in a very ſhort time.

When common reſpirable air is examined in this manner, by mixing it with an equal meaſure of nitrous air, the diminution of the mixture, when ſhaken with water, has been obſerved to be 90 or 100,

or 110, or even 120 parts in 200 of the mixture *, with frequent variation however of the reſult, though the trial be made with the very ſame materials, and in the ſame place.

For all theſe reaſons, I think that it may be worth while to try whether Mr. Scheele's way of examining the goodneſs of atmoſpherical air, or the quantity of vital air it contains at different times, and in different places, may or may not be preferable to this. Scheele's way was, as you may remember, by abſorbing the vital part by humid ſulphuret of iron filings.

To finiſh theſe remarks on the changes which a portion of the nitric acid undergoes while it diſſolves the metals, we may notice here, that part of it, on ſome occaſions, is reduced to an intermediate ſtate, between the ſtate of nitrous air and that of pure or perfect azotic gas. In this intermediate ſtate, it is a colourleſs elaſtic fluid or gas, like nitrous air, but has different properties.

1*mo*, It is much more abſorbable by water, and can be ſeparated again from the water by heat, unchanged.

2*do*, It is not converted into nitrous acid by the admixture of vital or of atmoſpherical, or of nitrous air; or to expreſs it more accurately, it does not unite with the oxygenous gas in theſe airs by ſimple mixture.

3*tio*, Though it be totally unfit for ſupporting animal life by reſpiration, it brightens and enlarges the flame of a candle immerſed in it;—and inflammable air mixed with it and fired, explodes much in the ſame manner as when it is mixed and fired with atmoſpherical air, but with a green flame. But it has very little power to maintain the combuſtion of charcoal, or of ſome other combuſtible ſubſtances.

4*to*, It may be produced or obtained from nitrous air, by expoſing

* In ſome of Dolomieu's experiments, the loſs was from 118 to 85, but the heat of the air was very different when ſo great a difference was obſerved. In the firſt caſe the wind was north-weſt, and the thermometer 55½. In the ſecond it was a ſirocco, or ſouth-eaſt wind, and the thermometer 82.

ſuch nitrous air to the action of ſubſtances or mixtures which have a ſtrong attraction for oxygen, ſuch as the ſulphuret of potaſh, the humid ſulphuret of iron, the muriat of tin, &c. From ſeveral phenomena which have occurred to me in experiments, I apprehend that the moſt expeditious way of obtaining it pure, would be to employ the neutral ſalts formed by the alkalis and the ſulphurous acid. I imagine that it is by ſuch intermedium that even the ſulphurets effect its production. Such matters firſt change the nitrous air into this intermediate kind, in two or three days, and afterwards, by a continuance of their action, change it completely into azotic gas, the bulk of it being at the ſame time very greatly diminiſhed. *(See Note 23. at the end of the Volume.)*

It may be alſo produced, and in a purer ſtate, by ſome particular modes of managing the action of nitric acid upon the metals, which we ſhall notice ſoon.

It was firſt diſcovered by Dr. Prieſtley, who gave it the name of *dephlogiſticated nitrous air*, on account of its promoting the burning of a candle, and having the power to brighten and enlarge the flame of it. He diſcovered ſeveral different ways of producing it, and made many experiments with it. But its nature has been beſt illuſtrated and explained by the ſociety of philoſophical chemiſts at Amſterdam, in conſequence of an ingenious inquiry, and a great number of experiments they made with this view. (See a very good account of theſe experiments in the *Analytical Review*, vol. 17. p. 356.)

They are of opinion, that, like nitrous air, or nitrous gas, it is a compound of azote and oxygen, combined by chemical attraction, but that it contains leſs oxygen than nitrous air does, though a greater quantity than that contained in atmoſpherical air. But beſides, in the air of the atmoſphere, the oxygen is cloſely combined with the latent heat only, or is in the form of a gas, ſimply mixed with azotic gas, whereas, in the ſort of air which we are at preſent deſcribing, the oxygen is combined, as I ſaid juſt now, with the azote, by chemical attraction.

The chief reaſon for thinking the union of azote and oxygen different in theſe two compounds is, that the peculiar qualities of this laſt take place at a pretty preciſe proportion of the ingredients, ſomewhat like other chemical combinations, when a mutual ſaturation takes place. I cannot ſay that this is a very ſtrong argument, although it is not without ſome weight. But it is more difficult to account for its increaſing the flame of a burning body, while nitrous air, which contains more oxygen ſimilarly combined, ſo far from having ſuch effect, extinguiſhes flame in an inſtant.

The proportions of oxygen in theſe different gaſes, or airs, are thus ſtated by theſe gentlemen, from ſome accurate experiments:

1*mo*, The atmoſpherical air is known to contain 27 or 28 parts of oxygen gas, or vital air, in 100 parts of the air.

2*do*, The air or gas we are now deſcribing contains 37 or 38 parts of oxygen in the 100.

3*tio*, And nitrous air contains 68 parts.

Theſe gentlemen have given a new name to the gas we have juſt now deſcribed: They name it *gaſeous oxyd of azote*. But this name is juſt as proper for nitrous gas, which is, like the other, *azote, in the ſtate of an oxyd*, or combined with oxygen, but with leſs of it than what is neceſſary to form an acid. It would have been better, therefore, to have named the gas we have been conſidering, *the leſs oxydated nitrous gas*, or, *the leſs oxydated oxyd of azote* *.

They have alſo made an ingenious attempt to explain its peculiar properties, eſpecially the power it has to promote the burning of a candle, and to brighten and enlarge its flame, although breathing animals cannot live in it a moment. Theſe apparently inconſiſtent qualities they impute to the peculiar mode of combination of the elements of this gas, which are ſo ſtrongly united, that the oxygen,

* Surely the name *nitrous oxyd*, given it by Chaptal and others, is more agreeable to the general plan of the French nomenclature. This compound ſeems to be in the ſmalleſt poſſible degree of oxydation. EDITOR.

though it has power to act on hydrogen with the assistance of heat, has very little power to act on carbon; and accordingly, the gas has very little power to promote or sustain the inflammation of charcoal. But in the respiration of animals, it is necessary that a carbonaceous principle be discharged from the blood, which carbonaceous principle is dissolved and carried away from the lungs, by respirable air in the form of carbonic acid gas; whereas the gas we have now described cannot serve this purpose. But it can serve for sustaining the flame of a candle, for this reason, that tallow, and all other oils, contain a much larger proportion of the hydrogenous principle than of any other in their composition: And the oxygen of this gas is in that state which disposes it to unite readily with hydrogen, while the hydrogen is separating itself from other matter, and before it has time to attract latent heat, and to expand with it into a gas. This state of hydrogen was named by Dr. Priestley the nascent state of inflammable air. We have already had several examples of a greater facility of union in this particular condition of things *.

The quicksilver, while it produces these changes in a portion of the acid, is itself changed into an oxyd, by its union with the oxygen which it has attracted; and this oxyd of the quicksilver is then combined with the remaining acid, or is absorbed by it †.

* Perhaps this explanation may not be thought to agree very well with the proportion of oxygen that appears, by the experiments of Lavoisier, La Place, and Monge, to be required for the inflammation of equal weights of hydrogenous gas and charcoal; the last requiring so much less than the former. Nor does it agree with the superiority that is assigned to carbon, in affinity for oxygen. EDITOR.

† This experiment, the solution of quicksilver in the nitrous acid, is, perhaps, the most perspicuous and instructive example of the general nature of metalline salts, and for this reason has met with particular attention from Mr. Lavoisier and his coadjutors. The character of the compounds, in their different states of oxygenation, are more distinct than in any other example. There seems to be several degrees of this, and each

The compound, or mercurial nitrate, being ſufficiently ſoluble, part of it will, in a day or two, cryſtallize at the bottom of the ſolution. The reſt continues diſſolved by the water of the acid, and forms a heavy, tranſparent, and nearly colourleſs fluid, very acrid and corroſive with reſpect to animal and vegetable ſubſtances. A drop of it makes an indelible black mark on the ſkin. The ſalt which it contains is ſometimes more, ſometimes leſs ſoluble in water, according to the quantity of acid with which the metal is combined, and in proportion as it is new, or has been long kept; for the ſame thing happens to it in ſome degree as to the ſolutions of iron. The metal which, while it is diſſolved, is evidently oxydated to a certain degree, by decompounding a part of the acid, becomes ſomewhat more oxydated afterwards in the ſolution; it therefore becomes leſs ſoluble, or requires a greater quantity of acid to keep it diſſolved, and with that acid it forms a compound not quite ſo ſoluble in water as the ſimilar compounds which contain the mercury in a leſs oxydated ſtate.

I may farther obſerve, that the ſolubility of the nitrate of mercury varies exceedingly with the temperature of the water. Water boiling hot takes up a great deal more, which is depoſited on cooling, in cryſtals. Nay, for the ſame reaſon, the acid will diſſolve more of the mercury, by the aſſiſtance of heat, and this is ſpeedily let go in cooling, and is of a different kind, as we have ſeen already, from what is obtained from the metal when it is diſſolved in a cold temperature, being more oxydated. Alſo, if we add a great quantity of diſtilled water to a ſtrong fluid ſolution, we have a precipitation of an oxyd, yellowiſh, if hot, and white, if cold: A ſmall redundancy of acid prevents this precipitation; ſo various are the appearances of this *Proteus metallorum*. But theſe differences are ſimilar, as I have ſaid, to what we ſee in iron; and they are

has a uniform effect, even on the ſtructure of the cryſtals. They are alſo very diſtinguiſhable, by the differences in their affinity for water, being ſo ſingularly and uniformly affected by its being hot or cold. EDITOR.

produced in the ſame way, or by the ſame cauſes, only more diverſified.

The nitrate ſalt of mercury has attracted much notice. It was tortured by the alchemiſts into a thouſand forms, being the produce of their favourite mercury, on which they profeſſed to build their greateſt hopes, and of the wonderful acid, which manifeſted the moſt remarkable and important properties. This precipitate is white or yellow in its firſt preparation, in the circumſtances I have conſidered: But, if long continued in a low heat, it becomes of a full red, perfectly ſimilar in appearance, and alſo ſimilar in many of its properties, to the *mercurius precipitatus per ſe.* It is called RED PRECIPITATE.

This compound is much uſed in medicine and ſurgery, as an eſcharotic, or cautery, for deſtroying fungous fleſh, &c. It has alſo become of great value to the philoſophical chemiſt, as affording the readieſt method for obtaining oxygenous gas in its pureſt ſtate. It is, therefore, of importance to prepare it in the moſt perfect manner, and particularly, to prepare it ſo as to be uniform in the proportion of oxygen it contains.

When the mercurial nitrate is ſimply evaporated to dryneſs, eſpecially when the precipitation has been partly effected by cold water, it is white, or yellowiſh, for which reaſon it has been called NITROUS TURBITH. If it be expoſed to a very low red heat in this ſtate, a conſiderable portion of acid is driven from it, and becomes of the fine full red colour, fit for the market. When this is done in a ſand bath, it frequently happens that before the central parts and ſurface have acquired the proper colour, the part at the bottom has been deprived of its oxygen, and the mercury revived. Dr. Higgins, therefore, performs this proceſs in a deep porcelain diſh, under a muffle, applying the heat all around, and covering the diſh with a glaſs plate. A ſmall portion of mercurial muriat uſually exhales in this proceſs. It ariſes from impurity in almoſt all the nitric acid that we can get; even a little of the nitrate itſelf ſometimes goes off. Chaptal, to have it in per-

fection, with a rich colour, pours freſh nitric acid on it, and diſtils it to dryneſs, three times.

I ſaid that, in the ſtate of a nitrate, this compound exhibited certain uniform differences in the form and ſtructure of its cryſtals. When the ſolution has been made without the aſſiſtance of heat, and the mixture kept cloſe during the proceſs, and if it be allowed to evaporate ſpontaneouſly, the cryſtals are thin ſquare plates, whoſe four ſides are formed into an edge, like that of a ſtone-cutter's chizel, and having the four angles cut off; that is, the cryſtals are formed of two tetrahedral pyramids, joined at their baſe, and having the angles cut off. (*See Romé de l'Iſle*, No. 38. VI. 11.)

But if the evaporation has been promoted by conſiderable heat, the cryſtals are flat-pointed ſpiculæ, having the flat ſide elegantly ſtriated in an oblique direction, like a ſword blade which has been ground by holding it very obliquely on a rough ſtone. If the ſolution has been effected by heat, the cryſtals are alſo flat ſpiculæ, like lancets; but the ſtriæ are now parallel to their lengths. This pointed form of all the cryſtals has been much inſiſted on by the mechanical chemiſts, in their attempts to account for the corroding powers of the mercurial nitrate, but, unluckily, the moſt corroſive are the cryſtals in flat plates.

Mr. Fourcroy has treated this ſubject with the ſame diſtinctneſs and perſpicuity as the ſolution in ſulphuric acid; and his analyſis of the different ſtates of the nitrate ſeems to me very judicious and inſtructive.

The muriatic acid, in its ordinary ſtate, has little power to act on mercury in its metallic form. This is a conſequence of the weak power, or rather *want of power*, in this acid to oxydate the metals; and they muſt be oxydated in ſome degree, in order to form compounds with acids. But the muriatic acid oxygenated by manganeſe, readily unites with metals in general, and forms a ſaline compound, the oxygen being in this caſe ſupplied to the metal by the acid. We can therefore eaſily obtain a compound of mercury and the muriatic acid, by employ-

ing this acid in its oxygenated ſtate. Or, if the quickſilver be firſt oxydated by air and heat, or by other acids than the muriatic, that acid will then readily unite with it, and even ſeparate the other acids from it.

Whether it has in this manner ſeparated the mercury from another acid, or diſſolved the mercury calcined by the action of heat and air, no difference can be perceived in the muriat. If for example, *mercurius calcinatus*, and red precipitate (accurately prepared) are diſſolved in ſeparate quantities of muriatic acid, no difference whatever can be perceived. This muſt be received as an abundant proof, that red precipitate contains no nitric acid, or any thing that it may not acquire by ſimple expoſition to heat and air.

The compound of the muriatic acid and mercury is ſoluble in water, but not ſo eaſily ſoluble as the compound with the nitric acid.

The uſual method, therefore, for combining quickſilver with the muriatic acid is, firſt to oxydate or diſſolve the metal with another acid, the nitric for example, and then apply to it the muriatic, which can be applied effectually by ſeveral different ways. We can apply it pure, or combined with an alkali, as in common ſalt.

When applied pure to the mercurial nitrate in ſolution, a copious precipitate, or rather coagulum, is immediately formed. This is uſually called the white precipitate of mercury. If we apply common ſalt, or any earthy muriat, we have ſimilar precipitate of mercury, and a neutral or earthy ſalt in ſolution.

If, however, we uſe the oxygenated muriatic acid, we do not obtain the ſame precipitate, becauſe the mercurial muriat in this caſe is very ſoluble in water, whereas the common muriat is far leſs ſo, indeed ſcarcely ſoluble, requiring almoſt 2000 times its weight of water, according to Beaumé and Lemery. The muriat, and the oxymuriat (as the French call it) of mercury, differ alſo in many other important properties.

But when the muriat of mercury is formed by theſe methods, the

ſeparation of it afterwards from the other acids, or ſalts, which are in the mixture, is very difficult. Theſe methods, therefore, are not convenient for practice, and a different one is commonly followed, by which this muriat is formed, and at the ſame time *ſeparated by ſublimation* from the other materials employed in the proceſs; this muriat being totally volatile in a moderate heat.

The proper materials for this purpoſe are,

1ſt, The quickſilver, reduced either to an oxyd, or to a ſaline compound, by the action of the nitric or ſulphuric acid.

2dly, Materials which, when heated, will ſupply to the quickſilver a proper quantity of muriatic acid in the form of dry vapour. You will find in Neuman's Chemiſtry a copious liſt of all theſe mixtures for procuring a combination of mercury with the muriatic acid.

The proceſs which was formerly moſt generally recommended in chemical books, was to mix a dry nitrate of mercury in powder, with an equal quantity of common ſalt, and as much exſiccated ſulphat of iron, and to ſublime this mixture. This is a ſure proceſs for obtaining a perfect corroſive muriat of mercury.

Neuman ſays, and I believe he ſays truly, that thoſe proceſſes in which the nitrous acid has acted, produce a more complete union of mercury with the acid. The mercury is more completely oxydated by this previous treatment, and will therefore unite with a greater quantity of the acid, and make a more active or corroſive compound. The truth is, that the metal attaches to itſelf a greater quantity of unmixed oxygen than it can obtain in any other way, and it is on the abundance of oxygen that the corroſive nature of the muriat entirely depends. But the proceſs now practiſed is ſimpler.

The quickſilver is firſt combined with the ſulphuric acid, and the ſulphat mixed with dry common ſalt in fine powder, and this mixture is ſublimed. This is Neuman's ſeventh proceſs. The ſulphuric acid quits the quickſilver to join itſelf to the alkali of the common ſalt, forming with it Glauber's ſalt, or ſulphat of ſoda; while at the ſame

time, the muriatic acid unites with the oxyd of quickſilver, and they ſublime together in the form of a corroſive muriat of quickſilver. The ſulphat of ſoda not being volatile, remains at the bottom of the ſubliming veſſel.

This compound, when well made, diſſolves totally in water, but requires about nineteen times its weight of water.

When it is leſs ſoluble than uſual, we find that it will effervesce with nitric acid, being in a ſtate which reſembles in ſome degree another preparation, to be mentioned preſently, in which the mercury is redundant, corroded, but not perfectly oxydated; and therefore it decompoſes the nitric acid. It diſſolves more eaſily, if ſome muriatic acid be added, or ſal ammoniac, or common ſalt; the muriatic acid in theſe ſalts acting in ſome degree, in conſequence of the force with which it attracts the quickſilver. It is pretty extraordinary that two volatile ſubſtances, often ſublimed together, ſhould become more fixed: Yet this happens with mercurial ſublimate, and ſal ammoniac.

It muſt be conſidered as a triple ſalt. It is an ancient preparation, and was called *ſal alembroth*, *i. e.* ſalt of the wiſe, or of the artiſts, by the alchemiſts. It cryſtallizes readily, by cooling the ſolution made in hot water.

This preparation was called the *corroſive ſublimate of mercury*, both on account of its being in fact very acrid and corroſive, in conſequence of the quantity of muriatic acid it contains, and alſo to diſtinguiſh it from another ſublimate of mercury which reſembles it a little in external appearance, but is quite free from any corroſive quality. It is now called the *hydrargyrus muriatus*. This *mild ſublimate*,—*mercurius ſublimatus dulcis*, or *calomelas*, or *hydrargyrus muriatus*, as it is now called, is produced by a proceſs which was contrived at random, in order to correct the corroſiveneſs of the former preparation.

Corroſive ſublimate is carefully mixed, by trituration, with an equal quantity of mercury, or with as much as can be ground with it, ſo as completely to diſappear; and this mixture is then ſublimed. It

riſes very imperfectly ſublimed in the firſt ſublimation, and therefore of a dirty colour. Repeating the whole proceſs makes it whiter, and by a third ſublimation, we have it in its beſt ſtate,—a white ſtriated maſs. The proceſs is exceedingly hazardous to the workman who mixes the materials, for the dry powder is apt to be received into the lungs, and a very ſmall quantity may be fatal. This is remedied in a great meaſure by adding a little water.

The compound is a *corroded mercury*, quite inſoluble and inſipid, having no more taſte than the mildeſt preparations. In it the mercury is much leſs oxydated than in corroſive ſublimate.

I called this a random proceſs, becauſe at the time of the firſt preparation of this drug, the chemiſts had no knowledge of any properties of mercury which could lead them to expect an intimate combination. Nay, to this hour it is not eaſy to ſay what is the exact nature of it. The mercury is here not merely oxydated, but combined with the acid, in a ſtate intermediate between that of an oxyd and a muriat. Beaumé, a very judicious and experienced pharmaceutiſt, affirms, that by reaſon of the great difference in the volatility of corroſive ſublimate and ſweet mercury, the two cannot be uniformly mixed by any number of ſublimations, and recommends, as the only way of freeing the drug from corroſive quality, to boil it with water, and a little ſal ammoniac, by which all the corroſive part is diſſolved.

This compound is not very different from what may be obtained by diſſolving mercury in the nitric acid, for it may be ſaturated with metallic mercury without allowing the formation of nitrous gas; and then pouring muriatic acid on the ſolution, a ſalt immediately falls down, ſcarcely diſtinguiſhable from mercurius dulcis.

The extremely corroſive nature of the mercurius ſublimatus is very evidently owing to the action on the inflammable matter in the ſubſtances corroded by it. Mr. Berthollet, while he held the Stahlean doctrine, attributed the corroſive quality of all metallic ſalts to their

action on the phlogiſton. His chief arguments were drawn from his experiments with this compound. When digeſted with vinous ſpirits, a conſiderable portion became ſweet mercury, and ſome was revived. When diſtilled along with oils, the mercury ſublimed in a metalline form, and the oil was rapidly deſtroyed, and left a prodigious quantity of charcoal. He now explains the ſame phenomenon by the powerful action of the oxygen. No doubt there is a rapid combination of oxygen with the inflammable matters. But we do not ſee how the combination of it with the metal tends to promote its combination with other ſubſtances; and I am by no means certain that the corroſive ſalts are more ſo than the acids themſelves. It were, perhaps, as juſt to ſay, that the natural corroſiveneſs of the acids is leſs mitigated by a combination with metals than with alkaline ſubſtances. Nor is Mr. Berthollet's opinion conſiſtent with the inoffenſive, nay ſanative quality of the martial and ſaturnine compounds.

It is found that there is no intermediate ſtate of oxydation between this of corroſive ſublimate and that of mercurius dulcis. When too little mercury has been triturated with the corroſive ſublimate, the mild ſublimate is ſtill formed perfectly mild; but, under it, next to the veſſel, we find the undecompounded corroſive ſublimate.

Thus we have ſeen how mercury may be combined with each of the three foſſil acids, and with ſome in different proportions, and in different ſtates.

Mr. Margraaf diſcovered that it may alſo be combined with the vegetable acids and with the fixed alkalis. And others ſince, by following his method, have found that it can be joined with a number of other acids.

Mr. Margraaf's method is to precipitate the mercury from a nitrate of mercury, by a pure fixed alkali. The precipitate diſſolves with effervеſcence in acetous acid, in vinegar, in the acid of lemons and of ſorrel, and even in Rheniſh wine. It requires digeſtion, but has no difficulty, and a great deal is diſſolved. See alſo *Fourcroy*, IV.

277. alſo the publication of the Dijon academy. The acetate of mercury is the baſis of Keyſer's pill.

With reſpect to the order in which the acids attract mercury, I ſhall only obſerve, that of the foſſil acids, the ſulphuric and the muriatic attract the metalline oxyd more ſtrongly than the nitric, as appears by the proceſs of the corroſive ſublimate. The ſulphuric acid finding the mercury properly oxydated, unites with it very readily, without the aſſiſtance of heat. Theſe two acids can alſo be combined with the mercury, by double elective attraction, or double exchange, when neutral ſalts which contain them are added to the ſolution of mercury in nitric acid, *e. g.* vitriolated tartar, or Glauber's ſalt, or vitriolic ammoniac;—and in the ſame manner, any of the compound ſalts which contain the muriatic acid.

Mr. Chaptal gives another proceſs extremely ſimple, and recommends it as producing a very perfect mercurius dulcis. Decompoſe mercurial water (ſolution of nitrate of mercury) by a ſolution of common ſalt. This throws down a white precipitate, which gives by ſublimation a mercurius dulcis. Scheele practiſed the ſame proceſs.

And by a ſimilar double exchange, this metal may be eaſily combined with the acid of tartar, or with that of ſalt of ſorrel, with which acids it forms a pearly precipitate, that is probably the preparation of mercury uſed in China.

It can alſo be combined in the ſame manner with the acid of phoſphorus.

Let us next conſider how it may be ſeparated again from the foſſil acids.—I ſaid already, that neither the ſulphat nor the muriat of quickſilver can be decompounded by heat;—the acid and metal in theſe compounds riſe in vapour together.

It is not ſo with the nitrat. The quickſilver remains in the form of a red oxyd, which, if the acid be expelled from it as completely as poſſible, by the continued action of heat, becomes very ſimilar to the calx or oxyd of quickſilver prepared by the action of air and heat.

By the deep colour of the vapours of the nitrous acid thus expelled from the quickſilver, as well as the appearances during its diſſolution, it is evident that the metal retains a great quantity of the oxygen of the acid. This oxyd is much leſs volatile than mercury, but if made red hot, it is totally converted into vapours or elaſtic fluids.

In collecting theſe vapours we get by a proper apparatus,

1*mo*, A quantity of nitrous acid in red fumes, but too ſmall to be condenſed.

2*do*, A ſmall portion of the quickſilver, which is combined with a part of the acid vapour, and forms with it a yellow ſublimate in very ſmall quantity.

3*tio*, The greater part of the quickſilver gradually diſtils over, reſtored completely to its fluid metallic form,—and

4*to*, Along with this a large quantity of vital air is obtained. This vital air is much purer than that which is got from nitre. Still, however, it is not perfectly pure. It is always tainted with a minute quantity of azote; and, I believe, with a ſmall portion of the nitrous acid, and even of the quickſilver itſelf.

This manner of preparing vital air was firſt diſcovered by Dr. Prieſtley.

He obtained it from *mercurius calcinatus*, by means of a burning glaſs, on the 1ſt of Auguſt 1774, and ſoon after, from red lead moiſtened with nitrous acid, by diſtillation in cloſe veſſels. Next month he went to Paris, and communicated his diſcovery of this wonderful fluid to Mr. Lavoiſier, and other members of the Academy of Sciences, then aſſembled at his houſe, who were ſurpriſed and delighted with the diſcovery. Returning to Britain, he engaged in ſo many reſearches that this had but a ſhare of his thoughts. Mr. Lavoiſier, with perhaps as much curioſity, had more of a philoſophical and ſcientific mind, and was a much better reaſoner than Dr. Prieſtley. He took a juſter view of this experiment, and ſaw at once its vaſt importance in philoſophical chemiſtry, and he repeated Dr. Prieſtley's experiment with an attention and exactneſs in all his meaſures, that was

altogether his own. He was the firſt who made it certain that mercury and other metals have the power to decompound the acid of nitre, and that we are thus enabled to obtain from it two different ſubſtances in their ſeparate ſtate, namely *nitrous air* and *vital air*. We obtain by itſelf nitrous air or nitrous gas, while the mercury is diſſolving; and we obtain the vital air afterwards, when we expoſe the diſſolved or corroded mercury to a ſtrong heat. And if we mix theſe two elaſtic fluids together, they immediately unite, or their fundamental matters or baſes unite, and form again nitrous acid.

It is plain that I here ſpeak of pure azote and pure oxygen. But it is very difficult to obtain theſe in a gaſeous form, and at the ſame time perfectly pure. The proceſſes for obtaining them always leave a taint of the ſubſtances from which they are obtained. It is not difficult to procure the azote very pure. Lime will free it from carbonic acid, and hepar ſulphuris will free it from oxygen. It is more difficult to procure vital air perfectly pure, and, eſpecially, free from azote. The red nitrate of mercury affords the beſt proceſs I know for it. But I have generally found it tainted with nitrous air, and with azote. I call your attention to this circumſtance, becauſe many of Dr. Prieſtley's experiments, by which he ſtill thinks that the theory of Stahl is ſupported, have had reſults which were certainly owing to ſuch impurities. I have particularly in my eye at preſent thoſe which he publiſhed 1792.

Thus, therefore, we can by heat alone recover mercury, which has been combined with the nitric acid.

We cannot in the ſame manner ſeparate the other two foſſil acids from mercury alone. I obſerved already, that they adhered to it too ſtrongly; but we can ſeparate them by other ſubſtances which have a ſtronger attraction for them than mercury has, and ſome of theſe bodies ſtill more readily ſeparate the nitric acid.

The ſubſtances which may be thus employed to attract theſe acids more or leſs perfectly from the quickſilver, are very numerous.

1*ſt*, Water applied in large quantity, and eſpecially if heated, will in ſome caſes produce a partial ſeparation. This is remarkable with reſpect to the ſulphat of quickſilver.

In waſhing the *mercurius vitriolatus* to make turbith, it is plain that the firſt boiling water takes from the mercurial calx the greater part of the acid. If, indeed, the mixture be allowed to cool, the calx reſumes a great part of the acid again, and becomes ſoluble. I have examined again and again the quantity of acid it contains in theſe different ſtates with care, and the differences are very ſenſible. It is difficult to ſay whether the heat increaſes or diminiſhes chemical action in this experiment. It is owing, in all probability, to the different proportions that are neceſſary, in different temperatures, for ſaturation, when we mix the compound of oxyd and acid with the compound of water and acid. If this proportion vary very much with reſpect to the laſt of theſe compounds, and very little with reſpect to the firſt, the phenomena will be what we obſerve. The nitrate is not ſo liable to be decompounded by water; but if largely diluted, it ſuffers alſo a little decompoſition. The muriat cannot be decompoſed by pure water alone.

2*do*, The precipitates by the fixed alkalis are of a reddiſh brown colour, approaching thereby to that of a pure oxyd of mercury. The reaſon is, that they are nearly pure oxyds, but not perfectly pure; they retain a ſmall portion of the acid. The fixed alkali has taken from them nearly the whole, but left a minute quantity, which adheres ſtrongly to the oxyd.

But the precipitates by the volatile alkali are remark bly different from theſe, and from one another, the nitrate giving a gray, and the muriate a white precipitate. The cauſe of this difference is, that the volatile alkali has much more power to ſeparate nitric acid from quickſilver, than to ſeparate muriatic acid from it. The volatile alkali has a ſtronger attraction for the nitric acid than for the muriatic acid; and, in addition to this, the mercurial oxyd does not retain nitric acid ſo ſtrongly, by far, as it retains the muriatic acid. In the white, or mu-

riatic precipitate, therefore, the mercury retains a conſiderable part of the acid, but not enough to render it ſoluble in water. In the dark-gray precipitate from the nitric acid, not only the acid is almoſt totally ſeparated, but a great part of the oxygen, and the quickſilver is reſtored, in part, to its metallic ſtate, by the ſuperfluous volatile alkali employed in forming the precipitation. The volatile alkali contains hydrogen to attract the oxygen. There is, however, combined with the mercury, a very ſmall remainder of the acid, and ſome of the volatile alkali. And it alſo retains a ſmall portion of the oxygen.

There aroſe great varieties and uncertainties on the ſeparation of mercury from corroſive ſublimate, by means of volatile alkali, depending much on the management. The reaſon is, that the acid ſeems to attract the mercurial oxyd more powerfully than it does the volatile alkali: For if mercury be diſſolved with ſal ammoniac, we inſtantly diſengage the alkali in a cauſtic ſtate. When this alkali is applied to corroſive ſublimate, it takes up ſuch acid only as is not neceſſary for ſaturating the mercury, and with this forms ſal ammoniac, leaving the reſt in the form of *mercurius dulcis*. Lemery obſerved this, by collecting and ſubliming the precipitate.

3*tio*, Quicklime, too, has power to attract the acid from quickſilver, and to precipitate it even from thoſe acids with which it is moſt ſtrongly combined. The change of colour, when much lime-water is added, ſeems to proceed from ſome action of the lime on the mercury which has not been examined. Half a drachm of corroſive ſublimate, thrown into a pound of lime-water, forms a yellow precipitate. This water is uſed, before ſubſidence, for cleaning the ſkin from pimples, tetters, &c. by the name of AQUA PHAGEDENICA.

Mr. Bayen diſcovered that the precipitate of mercury from the acids by means of alkalis, particularly the mild volatile alkali, or by lime-water, when ground with a ſmall portion of ſulphur, form an exploding compound, ſimilar to *pulvis fulminans*. If expoſed to heat, ſlowly increaſed, till it melt, it explodes with great violence, leaving a

reſidue, which ſublimation ſhews to contain mercury and ſulphur, by forming a good cinnabar. Something approaching to this had been obſerved by Brugnatelli, and others, and alſo very remarkable detonations by concuſſion. *(See Note 24. at the end of the Volume.)*

4*to*, Precipitation of mercury with milk may be mentioned here. A ſaturated ſolution of mercury with nitric acid, mixed with hot milk, gives a roſe-coloured precipitate of mercury; but when the milk is but juſt warm, it is of a purple colour. The intenſeneſs of the colour, and the firmneſs of the coagulum depended on the heat of the milk. They are ſoluble in all the acids, and are mild taſted. Other metallic ſolutions form a coloured coagulum with milk, in the ſame manner.

Many of the other metals have a ſtronger attraction for acids than mercury, but theſe, in general, precipitate it in its metallic form.

If a piece of clean copper be moiſtened with the nitrate of mercury in ſolution, and, after remaining a few minutes, be dipped in water, the ſurface will be found whitened; and if it be then rubbed hard with a clean and ſoft linen cloth, it will be as bright and white as ſilver. Putting this in a low heat, approaching to incandeſcence, the whitening film evaporates, and leaving the ſurface corroded by the nitrous acid. Had the copper been allowed to remain long enough in the ſolution, it would have been diſſolved entirely, and running mercury would have been found at the bottom of the veſſel. *(See Note 25. at the end of the Volume.)*

Such is the variety of appearances this metal can be made to aſſume by the action of ſalts,—red, yellow, white, black powders, white tranſparent ſoluble ſalts. In ſome of theſe ſtates it is much more fixed than before.

But however it is thus changed, it can be eaſily reſtored again to its natural form. It returns readily to its uſual form, when expoſed to heat, along with ſubſtances which can attract the acid from it, provided they ſeparate the whole acid, or nearly the whole, and reduce

the mercury to the ſtate of a pure oxyd. This oxyd, as I obſerved before, when heated to a certain degree in cloſe veſſels, recovers its metallic ſtate. The ſubſtances added are iron filings, or fixed alkali, or quicklime, &c. The reſtoration of the mercury is not called reduction,—but REVIVAL, and the mercury is ſaid to be REVIVED. This refers to its name ARGENTUM VIVUM.

When an oxyd of quickſilver is revived by the ſimple action of heat, and without any addition, it happens often that beſides the vital air, which it affords in great quantity, there is mixed with this a ſmall quantity of carbonic acid. This is ſuppoſed to have been attracted from the atmoſphere when the oxyd was too much expoſed to it, &c.

Neither mercury nor its oxyds can be made to combine with earthy ſubſtances, being too volatile.

Of the inflammables, ſulphur alone is diſpoſed to unite with mercury. Other inflammables are only employed to divide it. Sulphur may be combined with mercury, either by long and patient triture, or, more readily, by the aſſiſtance of heat, viz. by melting the ſulphur, and pouring in the mercury warm, and ſtirring well. The compound in either caſe is of an intenſely black colour;—hence, probably, called *æthiops*. When prepared by triture alone, the mercury is gradually divided and diſappears, the mixture becoming grey and blackiſh; but although the mercury appears to be perfectly incorporated with the ſulphur, it does not acquire the full black colour until it has been kept for ſome time, eſpecially if kept warm. Indeed, I find that the union by trituration is rendered at leaſt three times more expeditious, and the combination more perfect, by a heat juſt enough to make the ſulphur emit a ſenſible ſmell;—perhaps a little more heat would ſtill improve the proceſs. But ſtill, after the longeſt keeping, the mercury and ſulphur are more eaſily ſeparated than when mixed by fuſion. When the mixture is made by heat, they are more perfectly combined. But if they be made too hot, heat and flame are produced, ſeemingly

by a ſudden extrication of heat in the very act of union. This again ariſes from two cauſes: 1*ſt*, The compound may have a leſs capacity for heat than the ſum of the ingredients. 2*dly*, In the act of combination the mixture becomes ſtiff, and ſometimes hard. The heat therefore which makes an ingredient in their fluid forms, as latent heat, now emerges in ſufficient quantity to kindle the ſulphur. One part of ſulphur is capable of forming a perfectly uniform æthiops with five or ſix, or even ſeven parts of mercury. They are united together in this proportion for obtaining another preparation of mercury, viz. CINNABAR or VERMILLION, by a briſk ſublimation, in oval or oblong veſſels of coated glaſs, or of earth.

This preparation forms a very conſiderable manufacture, chiefly carried on in Holland, to ſupply the market with the great quantity uſed in painting, and for medicinal preparations; and the deſcriptions given by authors of approved proceſſes are numerous, and have conſiderable varieties. The moſt valuable property of the compound is the richneſs of its colour. When this is very deep or full, a moderate quantity of this expenſive article bears dilution with a great deal of other colour. The fulneſs of colour correſponding alſo to its purity, becomes a general teſt of its goodneſs. The attention of the artiſts is, therefore, chiefly directed to this circumſtance. It is found beſt to uſe an æthiops prepared by fuſion. That obtained by trituration and digeſtion is apt to ſeparate, in part, in the ſublimation. Stahl's proceſs, or that in the London Pharmacopœia 1788, ſeems to me the eaſieſt and beſt.

The mercury is made hot, and poured into the melted ſulphur, and the mixture carefully ſtirred. The flame ſhould be extinguiſhed by covering the mouth of the pot. The compound is then powdered and ſifted, and rammed into an oval ſhaped veſſel, ſo as to fill one-third of it. This is ſet in ſand up to the neck, and has its mouth open, in order to allow the eſcape of a fuliginous vapour of uncombined materials.

When theſe fumes are condenſed, they form a maſs as black as pitch. It is compoſed of the ſuperfluous ſulphur, and this is blackened by a ſmall quantity of the metal looſely combined with it. The ſublimation is carried on with a briſk heat, and it produces a very good cinnabar. Beaumé ſays that two or three ſubſequent ſublimations greatly improve its colour.

The ſublimate is a ſolid cake, of a blood red colour, which grinds to a red, ſo much the brighter as it is more levigated. It may be made ſo fine as to become too pale. Chemiſts have wondered at this red colour, imputing it to ſome kind of oxydation; and indeed an experiment of Lemery's ſeems to confirm this. Vitriolic acid renders it white, and fit to afford turbith; and the operation is accompanied with efferveſcence. Now we know that the acid does not attack it till it be oxydated.

Hoffmann mentions a proceſs by which he produced cinnabar without ſublimation. He mixed running mercury with the volatile tincture of ſulphur, that is, the compound of ſulphur and volatile alkali. The mixture was long agitated violently. It ſoon became black, and at length grew a beautiful red, and a perfect cinnabar. Beaumé deſcribes the ſame phenomenon as a diſcovery of his own.

Mercury is alſo ſaid to be affected by the fat oils. In particular, it is ſaid to acquire ſome ductility, if poured boiling hot into lintſeed oil. I have not obſerved any thing of this ſort, nor can I indeed have any notion of the ductility it can acquire. A ſolid that is brittle or friable may become ductile: A fluid cannot; it may be rendered ſluggiſh, clammy, and perhaps viſcid or tough, like melted glaſs, or ſealing wax; but I have never obſerved this change produced on mercury by the treatment now mentioned.

All theſe combinations of mercury with ſulphur are decompoſed, and the mercury revived again, by diſtillation with quicklime, fixed alkali, iron filings,—all of which retain the ſulphur. The mercury obtained from cinnabar is thought to be the pureſt that can be had; and

that obtained by means of iron filings is thought to excel the reſt. I am ſenſible of its having a more perfect colourleſs brilliancy. Its denſity is alſo the greateſt.

Relation to other Metals.

Mercury unites with all the metals except iron, arſenic, and platina. With the regulus of antimony, indeed, it unites very imperfectly, as we ſhall ſee in a little; and its more intimate union with the other metals will alſo be conſidered in their places.

Although arſenic does not unite with mercury, it affects the mercurial compounds, and is itſelf affected in a particular manner. If reguline arſenic be heated with twice its weight of the mercurial muriat (corroſive ſublimate) in the way of diſtillation, the vapours condenſe into an oil-like liquor, part of which grows gelatinous, and almoſt like very ſoft butter which has been melted, being grumous or a little granulated, which I take to be an incipient cryſtallization. When this has finiſhed, the vapours condenſe into metalline quickſilver.

This is a curious enough proceſs. Neither the mercurial muriat, nor the regulus of arſenic, are ſo volatile as this compound; and the regulus is not ſo volatile alone as mercury is. The fluid and gelatinous matter are a compound of arſenic and muriatic acid. Water decompoſes it in the ſame way as it does other metalline ſalts, that is, it ſeparates it into two parts, one of which is nearly in the ſtate of an oxyd, and the other contains this oxyd diſſolved in the acid. This oxyd is an intermediate ſtate between that of the arſenical acid and an arſenical oxyd.

I may remark on this occaſion, that mercury clears the acid of arſenic (white arſenic) from ſulphur and other inflammable matters which frequently make it foul. With the ſulphur it forms an æthiops, which yields cinnabar in the uſual way. I do not ſee ſo well how mercury can ſeparate the other impurities; and it is the more remark-

able, becauſe all other metals (ſilver and gold excepted) render arſenic foul.

I may alſo remark, that all the metals, when they decompoſe the muriat of mercury, form the ſame kind of butter-like compound; and it is moſt violently corroſive, deſtroying all organized bodies in a minute. Leaks in the diſtilling apparatus are, therefore, productive of the moſt fatal conſequences to the operators.

Mercury is ſuſceptible of mixture, in ſome manner, with all the other metals. And ſuch mixtures, called *amalgamas*, are of different conſiſtency, according to the proportion of the ingredients. If there is little of the other metal, they are fluid; if more, they are ſoft, like paſte or butter. If there is leſs mercury than an equal weight, they form a ſort of ſolid, more or leſs brittle and friable, in proportion as there is more or leſs mercury. The colour of theſe mixtures is always white. In amalgamas that are very ſoft or fluid, the mercury is in two different ſtates. Part of it is fluid, and nearly pure; the other part is united to the metal in a ſolid form, in the ſame manner as water is united to ſalt in cryſtals of ſalts. This ſolid matter, compoſed of the metal and part of the mercury, is felt like gritty grains in the amalgam: Or ſometimes it actually forms oblong cryſtallizations in it. Thus, if we diſſolve gold in boiling mercury, ſo as to form a ſoft amalgam, and then allow it to cool, the gold cryſtallizes or concretes with part of the mercury into ſpicular concretions, which are felt by the fingers. Hence amalgams, if fluid, can have part of the mercury imperfectly ſeparated by expreſſion through leather; but long triture, or long digeſtion, ſeems to produce more intimate union. It can be ſeparated, however, by diſtillation.

Upon the diſcovery of theſe preparations of mercury, in mixture with the different metals, have been founded the arts of ſeparating gold and ſilver, but eſpecially gold, from their matrices, (of which hereafter); alſo the art of foiling glaſs for mirrors; and that of gilding ſilver, copper, or braſs.

The proceſs for foiling glaſs mirrors is performed in the following

manner. The glaſs is laid flat on a very ſmooth and firm table. A ſmall border is made all round the edges, to hold in the mercury. The glaſs is then wiped very clean; and ſometimes rubbed over with a piece of ſoft leather, on which a little amalgam of mercury and tin has been ſpread. It is then covered all over with tinfoil; and mercury is poured on it, till the border is full. The mercury penetrates the tinfoil, and makes it lie cloſe to the glaſs, like a wet cloth. Indeed mercury penetrates the tinfoil juſt as water penetrates and ſoftens a cloth. When this has remained ſome time, the mirror is ſlowly raiſed on one edge, that the ſuperfluous mercury may run off; and it is allowed to ſtand in that poſition ſome days. Thus all the mercury not combined with the tin gradually ſubſides to the lower edge, leaving only what is neceſſary for keeping the tinfoil adhering to the glaſs plate.

Glaſs globes are coated on the inſide, by warming them very much, and pouring in ſome fluid amalgam, which adheres to the glaſs like water. By turning the globe round and round, the whole inſide may be thus ſmeared with the amalgam, ſo as to look like a metal globe highly poliſhed; but when held between the eye and the window, we diſcover that it is covered only as with a cobweb of the metal.

Silver and braſs are gilded by ſmearing them with an amalgam of mercury and gold. This makes them as covered with ſilver. The piece is then put into an oven, and the heat evaporates the mercury, leaving the gold adhering to the piece, in the form of a dirty brown powder. This is now gone over with a fine burniſher, made of ſteel or of hæmatites, highly poliſhed. This flattens down all the particles of the gold, ſpreads them out, and cauſes them to adhere, while it alſo poliſhes them. Copper and braſs acquire a ſkin that is undiſtinguiſhable from gold. But this gilding on ſilver has always a brown colour, very diſtinguiſhable. Moiſtening the ſurface of the piece with aquafortis cauſes the gilding to be more uniform and adheſive: For whenever the mercury touches the wet ſurface, the metalline nitrate adhering to it is decompoſed by the copper, and ſome mercury is left on it in a

metalline ſtate. The buttery amalgam unites with this very readily, and when the mercury is expelled by heat, the gold remains. Without this precaution, parts of the ſurface refuſe to let the amalgam attach itſelf to them. In conſequence of the ſame properties, it may alſo be applied to ſome uſeful purpoſes in medicine and ſurgery,—to diſſolve a lead ball, a piece of leaden tube, or probe, in the bladder; alſo to take off a ring from a ſwelled finger.

All the metals exhibit a peculiar appearance, when employed to decompoſe the muriat of mercury. They unite with the acid in a ſoft buttery form. Another general circumſtance in this decompoſition is, that this butter is more volatile than the muriat, and even than the mercury, although the metal employed may be much more fixed. Theſe compounds will be mentioned in courſe; but I thought it proper to make you notice theſe general characters.

Ores, or Origin.

Mercury is ſcarcer than gold. The only mines are at Almaden, in Spain; Idria, in Hungary; in the Duchy of Deux Ponts; in Friuli, in Italy; and in the Eaſt and Spaniſh Weſt Indies. Small quantities are ſometimes found in France and Britain. Virgin, or fluid mercury, is often interſperſed through other minerals; but the moſt common ore is cinnabar. The fluid mercury is oftenеſt found where cinnabar is moſt abundant. I think that the rarity of this metal, and even of ſmall portions of it mixed with other ores, is an abundant proof that there is no ſuch thing as a *mercurial principle*, the baſis of metallization. Were it ſo, we ſhould find imperfect metals very frequent, and in different ſtages of the progreſs, to the ſtate of perfect metal.

The account given of the chemical properties of mercury makes it eaſy to perceive how we ſhall obtain it from its ores. All the proceſſes, performed at all the mines, are diſtillations, managed with more or leſs art, and varied according to the nature of the ores. Even where

found in a fluid form, it is generally in globules, too ſmall to be ſeparated by the hand, or by pounding and waſhing. It is much eaſier to do it by diſtillation. The cinnabar ores are generally mixed with ſo much calcareous matter that no addition is neceſſary for ſeparating the ſulphur. When this is not the caſe, (as at Deux Ponts), ſlaked lime is mixed with the ore in the retorts. Theſe are placed in a row, in a long furnace like a gallery. Their necks project through holes in the ſides. To theſe are fitted receivers containing water, into which the mercury falls. At Almaden in Spain, a long row of earthen aludels go from each retort, down a gently ſloping terrace, and then up a ſimilar terrace, and terminate in a chamber, having a concave floor, and a tall chimney. The diſtillation is forced by conſiderable heat, and the vapours condenſe in the aludels, both in the deſcent and ſubſequent aſcent. What are not condenſed there are condenſed in the chamber. The ſloping poſition of the aludels cauſes the mercury to run out of the higher into the lower, on both ſides of the valley formed by the two terraces, and it all collects in the aludel at the bottom, This one has a ſhort pipe, or neck, in its under ſide, which is plunged into a hole cut in the ſtone which forms the gutter between the two terraces. The gutter is filled with water. From this conſtruction, it is plain the aludels have no communication with the air, except by the chamber. The diſtilled mercury, therefore, runs out of the lower aludel of each row, fills the hole in the gutter, and then runs over, with water above it, into the gutter. This has a very ſmall declivity towards one end. The mercury, therefore, runs along this gutter into a gutter at one end of it. Thus the diſtillation is carried on with rapidity; and there is no riſk of burſting the veſſels, or of the vapour eſcaping by any leaks.

Medicinal Preparations of Mercury.

The very great activity of mercury on the human body, and its effects when exhibited as a medicine, are ſo remarkable in the treat-

ment of many diſeaſes, that phyſicians have turned it into almoſt every poſſible ſhape; and the mercurial preparations are almoſt innumerable. In this reſpect it has but one rival in the foſſil kingdom, viz. antimony, the preparations of which are no leſs various. To paſs them by would be highly improper; but to deſcribe them all would require a winter's ſeſſion, and would be no leſs improper. I muſt content myſelf with conſidering them in two points of view. I ſhall deſcribe ſuch of them as indicate any ſingular chemical property of mercury and antimony, by which your chemical ſcience is improved. I ſhall alſo take particular notice of any connection or dependence that I can diſcover between the medicinal effects of the preparations, and the general chemical reſemblances that may obtain among the methods of preparing them. This will direct the medical chemiſt to ſuch treatment of the metals as are the moſt likely to produce the deſired medicinal effect. Thus will the philoſopher be inſtructed, and the artiſt directed. *(See Note 26. at the end of the Volume.)*

GENUS V.—ANTIMONY.

After mercury, I ſhall next conſider the brittle and volatile metals, which, on account of their wanting ductility, are called imperfect, or ſemi-metals; and antimony *(ſtibium olem)* being one of theſe, we ſhall take it firſt. It is the one to which the chemiſts and phyſicians have paid the greateſt attention, torturing it into an endleſs variety of forms.

Antimony is a dull ſilver-coloured metal, of the ſpecific gravity 6,7. Its ſurface exhibits facets, and a ſtar-like figure. This appearance proceeds from a cryſtallization, or arrangement of its parts in cooling. It is totally deſtitute of malleability, and can eaſily be beaten to powder. It is poſſeſſed of fuſibility and volatility. The vapours of it calcine to a white ſmoke, and condenſe on the ſurface of any cold body expoſed to them. Or if they are collected, and ſomewhat confined, in the cavity of a veſſel applied to receive them, they condenſe

into a matter compoſed of minute ſpicular cryſtals, very like ſnow, or flores benzoini, called *nix antimonii*,—ſnow of antimony; or by ſome chemiſts, ſilvery flowers,—*fleurs argentines*. You may ſee all theſe phenomena by heating a little bit of antimony with the blow-pipe on charcoal. There is here an evident inflammation. The white ſmoke is partly compoſed of an oxyd, formed by the action of the air, and it adheres to any cold body in form of a white powder. It is pretty highly oxydated. But when the heat of the maſs abates, and the vapours ariſe more ſlowly, and are leſs calcined, a part of them condenſes on the ſurface of the metal itſelf, appearing like a covering of ſnow.

We can alſo calcine this metal with an inferior heat, ſo as not to convert it into vapour. It muſt be beaten to powder, and ſpread out in a broad and ſhallow veſſel, and expoſed to a very gradual heat. The ſurface of the metallic particles ſoon becomes tarniſhed and duſty, and they are by degrees converted into a duſt, or earthy-like powder; firſt dark gray, or aſh-coloured, but by continuance of the calcination, yellowiſh, and at laſt white.

Theſe calces, or oxyds, are remarkable by proving all volatile, if expoſed to the action of heat and air at the ſame time, and when the vapour of them is condenſed by cold and a proper apparatus, they form the ſilvery flowers.

Some chemiſts have thought that there was a reſemblance between antimony and arſenic; and they certainly reſemble one another in this reſpect, that the calces of both, when in a ſtate of moderate calcination, can be converted into vapour very eaſily. But the calx of antimony differs from white arſenic in this point, that whereas white arſenic will evaporate in cloſed veſſels, or by the action of heat alone, without requiring the aſſiſtance of freſh air, the calces of antimony will not evaporate, except when expoſed to the action of both heat and air. If the acceſs of freſh air is excluded, they endure a very violent heat: And the effect of the heat in this caſe is to melt them in-

to a glaſs. They melt the more eaſily the leſs they have been calcined. And the glaſs thus produced has always a deep ruddy brown yellow colour, which is ſo much the deeper and darker, in proportion as the calx was leſs calcined.

All ſuch calces or glaſſes are reducible to a metallic ſtate: The leſs calcined, however, the more eaſily and completely. The reduction is performed by fuſion with charcoal duſt, or black flux, or fixed alkali and ſoap. So far of the effects of heat.

The greater number of the acids can be made to act on antimony in one way or another. Some attack it readily in its metallic ſtate; others better when it is ſlightly or moderately calcined,—but when it is greatly calcined few of them are diſpoſed to unite with it. Dr. Pearſon in his diſſertation on James's powder (*Phil. Tranſ.* 1791.) gives an account of a ſeries of experiments made with the view of comparing their different ſolubility; and it appears that the degree of calcination has a very ſteady connection with the ſolubility of the calces.

The action of the ſulphuric acid on antimony very much reſembles its action on mercury. It muſt be ſtrong and hot. The action is attended with efferveſcence and the eruption of fumes of ſulphurous acid; and towards the end of the proceſs, actual ſulphur. The efferveſcence being frothy, it is very troubleſome, riſing in the veſſel and running over. After ſome time, this ceaſes, and the liquor may be ſaid to boil rather than to efferveſce,—it is ſtill however the ſame elaſtic gas which it emits. At length, the metal is completely taken up, or changed, and we have a white precipitate, and a ſolution of a ſulphat of antimony. The precipitate is nearly a perfect oxyd. The ſolution will not cryſtallize by evaporation; but when reduced to a dry maſs, it immediately deliquiates again. The ſolution may be decompounded by alkalis, and gives an oxyd extremely difficult of reduction.

Nitric acid can ſcarcely be called a ſolvent of antimony, for its form

never diſappears. After remaining ſome days in the acid, the metal is only found divided, ſwelled up, and covered with bumps like colliflowers, juſt as in its calcination; the laminæ are ſeparated, and the interſtices filled with a white oxyd. All this is accompanied by a great change in the acid,—red fumes are emitted in abundance, and the liquor acquires a green colour. In ſhort the acid is decompoſed. When the materials are examined, we find the metal completely changed. There is a matter lying at the bottom, which, on examination, is an oxyd of the metal, with ſome exceſs of oxygen. The liquor contains a nitrate of antimony. Water cauſes ſome precipitation; and the remainder is the ſolution of a very deliqueſcent ſalt, which can be decompounded by an alkali. This precipitates an oxyd of antimony, which it is very difficult to reduce to the metallic ſtate.

Muriatic acid acts very ſlowly and languidly on antimony; but it acts on it, and diſſolves it with a ſlight efferveſcence. If, however, it be digeſted on antimony, it diſſolves it, and retains it, when nitric acid, either ſtrong or weak, is added to the ſolution; thus, making it evident that it attracts the metal. With care, the muriat may be made to cryſtallize in ſpiculæ, but it is extremely deliqueſcent.

The action of the marine acid on antimony is much promoted by adding to it a ſmall quantity of nitric acid. When this mixture is poured on the metal, we have at once a briſk ſolution, and the copious eruption of nitrous fumes, even although the quantity of nitric acid ſhould not amount to one-tenth of the muriatic. It is better however to add one-fifth. This mixture diſſolves a conſiderable quantity; and the muriat yields a very deliqueſent ſalt, which is alſo very fuſible and volatile,—and is parted by water, like the nitrate, yielding an oxyd, and retaining the true muriat; and this may be decompounded by an alkali.

Theſe phenomena, exhibited by antimony in the nitric and muriatic acids, are eaſily underſtood. The nitric acid contains oxygen very weakly united. Part of it unites with the antimony, and the oxyd,

being very little ſoluble in water, lies at the bottom of the liquid. The fumes are nitrous gas. The muriatic acid has its ingredients united too firmly, and does not therefore act on the metal without long digeſtion, and even then acts feebly. But a little nitric acid ſupplies it with as much oxygen as ſuffices for the oxydation of the metal; and the fumes which break out are nitrous. Indeed the ſimple addition of colourleſs nitric acid to the muriatic immediately emits the fumes. When we have got the metal into the ſtate of an oxyd, the ſolution goes on apace. In confirmation of this explanation, I muſt obſerve, that the oxygenated muriatic acid diſſolves the antimony with great facility, and produces the very ſame compound with that juſt now deſcribed.

This, however, is not the uſual or moſt complete way of effecting a combination of antimony with the muriatic acid. The proceſſes in common uſe are different, but they depend on the ſame principles.

In one of theſe proceſſes we mix ſixteen parts of corroſive muriat of quickſilver with ſix parts of the metal of antimony, both in powder, and apply to this mixture a ſubliming heat in a retort and receiver. The metal is in this caſe both oxydated and at the ſame time combined with the dry and ſtrong muriatic acid of the corroſive muriat of mercury. The oxydation is effected by the mercury, which being itſelf in a highly oxydated ſtate, or combined with a good ſtore of oxygen as well as with acid, transfers both the oxygen and acid at the ſame time to the antimony, which has a ſtronger attraction for them both than the quickſilver has. The antimony therefore is both oxydated ſufficiently, and combined with the acid,—the quickſilver reſuming its metallic form. In this, as well as in the ſimilar proceſs with arſenic and mercurial muriat, the mercury requires a greater heat to raiſe it in vapour than the antimonial muriat; and this laſt is even more volatile than the mercurial, though antimony is more fixed than mercury.

The new compound differs from the corroſive muriat of mercury

by being more eaſily melted than volatilized, whereas the corroſive mercury is more volatile than fuſible. The antimonial cauſtic or corroſive therefore riſes in vapours, which condenſe firſt into a fluid matter, on ſome of the cool parts of the retort, but when they reach parts ſtill colder, the fluid matter quickly congeals into a ſolid icy-like ſubſtance, which can be eaſily melted again, and congealed at pleaſure, melting with a gentle heat almoſt like tallow or butter. Hence the ancient chemiſts gave it the name of *butter of antimony*. Its colour is dark at firſt, but, by rectification, it becomes white or colourleſs like ice; a little ſuperfluous metallic matter and ſome impurities being thus ſeparated from it.

When we make further experiments with this compound, we learn that it has a ſtrong attraction for water. A very ſmall quantity of water diſſolves the greater part of it, or reduces it to a liquid form; and it readily attracts ſo much water from the air, if it be expoſed in open veſſels. As it is more convenient to keep and uſe it in a liquid form, it is commonly ſold liquid, by the name of *antimonial cauſtic*. In the laſt editions of the London and Edinburgh Pharmacopœias, this compound is called *antimonium muriatum*. It is very acrid or corroſive with reſpect to animal and vegetable ſubſtances. A little of it applied to the ſkin very ſoon burns or deſtroys the part. Whence antimonial cauſtic is employed to deſtroy fungous excreſcences from ulcers or other parts.

Water, added in large quantity to this compound, affects it in the ſame manner as it does the ſulphat of mercury. The water attracts and diſſolves the acid, leaving the metal in the form of a white oxyd, which, although waſhed with repeated additions of hot water, retains ſtill a ſmall part of the acid. It is called *powder of Algarotti*, from the name of an Italian phyſician, the inventor; alſo *mercurius vitæ*, though it contains no mercury. Nor does it contain any acid, if prepared with proper care. It ſhould be a pure oxyd, pretty copiouſly oxydated.

Antimony unites alſo with the vegetable acids. The acetous and tartarous acids, and the acid of vinous liquors, diſſolve it, and become violent emetics. But theſe acids diſſolve it much better when it is ſlightly oxydated. They are medicines of great activity, and ſhould therefore be very accurately prepared. Unfortunately, it is very difficult, if poſſible, to reduce them to the ſame ſtrength when prepared by different proceſſes; and the phyſician preſcribing his doſe by the effects of a preparation to which he has been accuſtomed, may produce very unexpected effects, when the ſame doſe is given of the medicine otherwiſe prepared. I think that the precipitate from the antimonial muriat has a greater probability of being uniformly the ſame than any other oxyd of the metal. It is, therefore, a good baſis for theſe vegetable additions.

Of the neutral ſalts, only nitre and ſal ammoniac act upon antimony. The firſt deflagrates, and the heat of deflagration volatilizes ſome of the metal. We thus get an oxyd whiter and leſs fuſible in proportion to the quantity of nitre. Nitre two parts, to antimony one part, gives an oxyd very white and unfuſible. The alkali of the nitre, mixed with this oxyd, is called *reguline cauſtic*.

Sal ammoniac preſents nothing particular, or different from its action on metals in general.

Of the inflammable ſubſtances, ſulphur readily unites with this ſemi-metal in the fire, and forms a fuſible compound, which bears a great reſemblance to the ſemi-metal by itſelf; but the ſulphuric compound has leſs brightneſs, and a darker colour, and more ſlender cryſtallizations.

The ſulphur can be ſeparated, and the metal recovered in its pure ſtate by different proceſſes; as,

1*ſt*, By roaſting the ſulphurated antimony, ſo as to evaporate the ſulphur, we get the metallic matter in the form of an oxyd, which retains very little of the ſulphur, and may be reduced to the metallic ſtate by melting it with black flux. The firſt part of this proceſs re-

quires patience and attention, on account of the volatility of the metallic matter. I ſhall take further notice of it afterwards.

2*dly*, Another method, which is ſhorter, is to melt the ſulphurated antimony with an equal, or half its weight of black flux. The alkali joins the ſulphur, and a part of the metal in its pure ſtate ſeparates to the bottom of the veſſel. But by this method we obtain only a part of the metal. A conſiderable part is diſſolved by the alkaline ſulphuret; and if a pure alkali is uſed in place of black flux, it diſſolves the whole.

3*dly*, We can ſeparate the ſulphur by other metals, many of which have a ſtronger attraction for it than this ſemi-metal has. Iron is commonly uſed, either in filings, or ſmall nails, or the ſcraps from the tinplate-workers. A ſtrong heat is neceſſary. Thus the antimony ſettles to the bottom, the ſulphurated iron flows uppermoſt, and is ſeparated more eaſily, if ſome ſaline matter has been added to promote the fuſion.

When this metal happens to be combined with ſulphuret of alkali, it can hardly be ſeparated again, except in this manner, by melting the compound with other metals which have a ſtronger attraction for the ſulphuret. Other metals thus employed to ſeparate the antimony from ſulphur, or alkaline ſulphuret, are liable however to mingle with it a little, and to make it impure. For it is diſpoſed to mix with all other metals, if properly applied to them with a melting heat. Iron appears to have the ſtrongeſt attraction for it. With all the tough metals, it produces compounds more or leſs brittle. And beſides this effect on iron, it deprives the iron of its magnetic qualities and diſpoſitions to be attracted by the magnet. No other metallic ſubſtance affects iron in this manner *.

The method of ſeparating it from the different metals is various, according to the nature of the metal with which it is joined.

* I find that leſs than three parts of antimony to one of iron will not deſtroy the magnetiſm of the iron. EDITOR.

From gold or platinum it is ſeparated by evaporation, or the action of heat and air. From other metallic ſubſtances it is beſt ſeparated by the addition of ſulphur, or, in ſome caſes, by ſcorification, as from lead.

Such is the chemical nature of this ſemi-metal. It is one of thoſe which are produced by nature in large quantity in ſome places; and the ore of it is every where nearly of the ſame kind. Sometimes, though rarely, it has occurred in a ſtate of purity; but ſuch ſpecimens are very rare, and the quantity trifling. The moſt common ſtate in which it is found is combined with ſulphur; and I believe there is ſome variety in the proportion of the ſulphur to the metal in the different ores. Moſt of them contain a little arſenic: Its preſence is eaſily known by the white and ſilvery appearance of the ore, and by the orpiment which it yields by ſublimation. The appearance of theſe ores is very like that of the artificial compound of the metal and ſulphur. And the only operation which the metallurgiſts perform with theſe ores before they ſend them to the market, is to ſeparate from them the earthy and ſtony matters, or matrix, which happens to be combined with them.

This is done by the proceſs named in metallurgy *Eliquation*. The crude antimony is put into earthen pots, pierced in the bottom. Theſe are ſet upon other pots buried in the ground. The fuel is thrown in around the pots; and the fire kept in a uniform ſtate, by the judicious ſtructure of the furnace. When the ore is fuſed, it runs into the lower pots, and the earthy matters remain in the upper ones. It is frequently moulded in truncated conical loaves. As this is the only operation performed on this mineral to fit it for ſale, it comes into the hands of the chemiſts and druggiſts in this ſtate, in which the metal is ſtill combined with ſulphur, and may be conſidered as yet in the ſtate of an ore. They were accuſtomed to call it *crude antimony*, or ſimply, *antimony*. And the pure metallic part, when ſeparated from the ſulphur, has been commonly named *regulus of antimony*;

but the later chemiſts give the name of *antimony* to the pure metallic part; and to this compound, that of *ſulphurated antimony*, or *ſulphuret of antimony*.

It is therefore by working on this ſulphurated antimony, or crude antimony, as it is called, that moſt of the preparations of antimony are produced, in the art of pharmacy. By what you know already of the nature of its two conſtituent parts, I mean ſulphur, and the metallic ſubſtance which I have already deſcribed, you will now eaſily underſtand the changes it undergoes by the action of heat and air, or of different ſolvents, and other active ſubſtances.

Preparations of Antimony.

Before I begin to deſcribe the different preparations of this mineral, I beg leave to make a remark upon the whole of the ſubject, which will aſſiſt you to underſtand how theſe preparations differ from one another, in point of efficacy as medicines; for the general purpoſe of preparing crude antimony is to give it more or leſs medicinal efficacy, to make it either a ſtrong and powerful remedy for ſome purpoſes, or one that ſhall be mild and ſafe for others.

In the firſt place, there is good reaſon, from experience, to believe that antimony never acts as a medicine, except when diſſolved or combined with an acid, either before it is taken into the ſtomach, or in conſequence of its finding an acid there with which it unites. But in crude antimony, the metal neither is already united with an acid, nor is it much diſpoſed to join with the weak acid which alone it can meet with in the ſtomach. The ſulphur with which it is joined, and the uncalcined ſtate of the metal, are unfavourable to its being eaſily diſſolved by a weak acid. In order to make it eaſily ſoluble in the acid of the ſtomach, we muſt ſeparate more or leſs of the ſulphur, and *calcine* or oxydate the metal to a *moderate degree*. I ſay a moderate degree, for if we oxydate it very much, we again diminiſh its diſpoſition to be diſſolved. By taking away, therefore, more or leſs of the

ſulphur, and moderately oxydating the metal, we produce preparations which are capable of acting very powerfully; but their action is not always the ſame, or in proportion to the doſe. It depends on their meeting with acidity in the ſtomach, which is not always preſent there in ſufficient quantity to give them all their efficacy.

The ſureſt way to reduce antimony to a form in which it will act equally and ſtrongly (at leaſt ſo far equally as the different conſtitutions of different patients will permit), is to ſeparate the ſulphur, and combine the metal with an acid, ſo as to give it a ſaline ſoluble form before it is thrown into the ſtomach.

And now, having premiſed theſe remarks, we ſhall proceed to deſcribe the different preparations, in the order in which they are arranged in the table of them which I have put into your hands. *(See Note 27. at the end of the Volume.)*

The firſt is the *antimonium præparatum*, in both our pharmacopœias. It is crude antimony, reduced to a very fine powder, ſimply by triture and elutriation with water. I remarked already, that crude antimony has but little efficacy as a medicine, or is an exceedingly mild one. This is a conſequence of the ſtate of the metal in it, which is neither already united with an acid nor much diſpoſed to unite with the acid of the ſtomach, not being prepared by any degree of calcination, and having alſo the ſulphur adhering to it. The antimonium præparatum, is, therefore, never given when we propoſe to vomit or purge. It is only uſed to promote perſpiration, or to excite the other evacuations ſo gently that its effect is hardly perceived, and that the uſe of it may be continued conſtantly for ſome time; and to make it act even thus, the greateſt levigation is neceſſary. The antimonium præparatum is, therefore, crude antimony, reduced to this ſtate of a very fine powder ready for uſe. Kunkel, an eminent German chemiſt, is ſaid to have cured himſelf of a rheumatiſm with it. I once had an opportunity of perceiving that it ſometimes excites nauſea, and expels worms; a proof that it is not quite inactive. In preparing it,

we muſt be careful to avoid the baſe or broader end of the conical loaf into which it is moulded for ſale. If any impurities, or admixture of other metals are in the maſs, they are in this upper part. They ſcorify with part of the ſulphur, and being thus lighter than the reſt, float above it.

The next preparations are thoſe produced by the action of heat and air.

When crude antimony is expoſed to heat ſuddenly, the moſt of it evaporates, eſpecially if air be admitted. This is to be expected, as both the metal and ſulphur are volatile ſubſtances. Its evaporation is attended with ſome inflammation, viſible in the dark. By careful procedure, the ſulphur may be completely diſſipated by roaſting the powdered antimony. No ſuffocating ſmell will be perceived. A ſudden increaſe of heat would mar the operation, by melting the antimony, and thus diminiſhing its extenſive ſurface. As the operation advances, we may increaſe the heat without danger of melting. This may be continued till all the ſulphur is expelled. The metal now begins to attract oxygen, and grows gray, and at laſt white; and in this ſtate is a pure oxyd. Thus you ſee that by terminating the proceſs at different periods, we ſhall procure the metal in very different ſtates. It is therefore a matter of importance that it be conducted in a very uniform manner.

There is the ſame, or perhaps a greater variety, when the heat is ſo great as to cauſe the ſulphur attract oxygen. In this caſe we have ſuffocating fumes, &c.

The only preparations which have been produced by the action of heat and air are, the *flores antimonii ſine addito*, the *calx antimonii*, the *vitrum antimonii*, and the *vitrum ceratum*, *(Pharm. Edin.)* prepared from the vitrum.

To prepare the flores antimonii ſine addito, the ſulphuret is put into a crucible, or unglazed earthen veſſel. A ſet of aludels are ſet on it, and a pipe is inſerted by a proper opening in the ſide or lip of

the crucible. The fire being kindled, and grown pretty ſtrong, the fumes begin to ariſe, and then a pair of bellows are applied to the pipe, and a gentle ſtream of air is made to play on the ſurface of the materials, but in the moſt gentle manner poſſible. The metallic and ſulphurous fumes now riſe, and are condenſed in the different aludels. The ſulphur of the flores, being the moſt volatile of the fumes, riſes higheſt, and the oxydated flowers are contaminated by it ſo much the more as they riſe higher, or rather they riſe ſo much the higher as they contain more ſulphur. The artificial ſtream of air cannot be managed with ſuch delicacy as to preſerve that regular gradation that may be obtained in a ſmall quantity ſublimed without the blaſt. This preparation, therefore, is unequal and uncertain, and is now diſuſed.

Vitrum.——In making the glaſs of antimony, we begin by ſeparating the ſulphur, or the greater part of it, by the action of heat and air, and at the ſame time oxydate the metal to a moderate degree.

Both theſe objects are attained by performing the operation practiſed with ores of metals to free them from ſulphur. It is named *uſtulation.* The operation of uſtulating ſulphurated antimony is difficult on account of the fuſibility of this mineral, and of the volatility of its metallic part.

To diminiſh fluidity, ſome add charcoal duſt; others add common ſalt, which is eaſily ſeparated afterwards by water.

But the common way is to uſtulate it without addition.

It neceſſarily happens in this operation, that the metallic part is oxydated, while moſt of the ſulphur is evaporated. And, if the operation be properly managed, we have an oxyd of the metal of a gray or aſh colour, moderately oxydated, and with very little of the ſulphur remaining in it, and therefore in a condition to be eaſily melted into glaſs; for we have learned by experience that the preſence of a little of the ſulphur greatly promotes its melting into glaſs.

It is therefore by ſimply melting an oxyd of antimony, prepared in this manner, that the glaſs of antimony is obtained.

Vitrum ceratum is prepared (in order to mitigate the action of the vitrum antimonii) by kneading the pulverized glaſs of antimony with bees wax, and then burning away the wax.

The next preparations of antimony in the table are thoſe prepared with alkaline ſalts.

The fixed alkalis act readily on crude antimony, on account of the ſulphur which it contains, and with which they have a ſtrong diſpoſition to join.

Of this we have examples, when we apply theſe ſalts to the crude antimony, either in the dry way by fuſion, or in the humid way, in the form of watery ſolution. They act moſt readily and powerfully when applied in the way of fuſion. The alkali joins itſelf to the ſulphur, and forms a ſulphuret of potaſh,—a compound which has great power to act on the metals in fuſion, and to diſſolve even thoſe with which ſulphur alone cannot be combined. The metallic part of the antimony, therefore, does not ſeparate, or very ſeldom, and in ſmall quantity only. Commonly the whole mixture melts into one uniform vitrified-like maſs. If one part of fixed alkali and five of crude antimony are melted together, and ſome common ſalt added, which promotes their fuſion, we obtain a dark coloured vitriform maſs, once known under the improper name of *regulus antimonii medicinalis*. It is eaſily ground to powder, and gives a powder of a reddiſh brown, or a ſort of chocolate colour, which is inſipid on the tongue, and not ſoluble in water. It is a very mild preparation, but has a little more efficacy than the antimonium præparatum.

Larger proportions of alkali form maſſes which prove more or leſs ſoluble in water. Thoſe which contain one of alkali to two of crude antimony are ſoluble in hot water, not in cold. With larger proportions of alkali, they are ſoluble in cold water as well as in hot. With

two of alkali to one of crude antimony they are even deliqueſcent, or attract humidity.

The moſt proper name for all theſe compounds is alkaline ſulphurets of antimony.

When we apply water to them to diſſolve thoſe that are ſoluble, none of them are diſſolved completely. There is always a ſeparation of a reddiſh or browniſh ſediment, which is more plentiful in proportion as there is leſs alkali in the compoſition of the maſs. This ſediment is formed by a part of the antimony, and it is ſome of the more metallic part which thus ſeparates. The reſt, which in conſequence of this ſeparation is more ſulphurous, and has more alkali combined with it, remains diſſolved.

Beſide the way by fuſion, I obſerved before that we can form compounds of this kind in the way of watery ſolution, or, according to the language of the chemiſts, in the humid way.

Though the alkali, in whatever manner applied, acts by its attraction for the ſulphur chiefly, it diſſolves in this way alſo the greater part of the metal. It continues adherent to the ſulphur, and is diſſolved along with it. The ſolution, therefore, which we thus obtain, is a ſolution of an alkaline ſulphuret of antimony, which is rather more eaſily decompounded, and requires more water to keep it diſſolved, than a plain ſulphuret of potaſh; and the cauſe of this is, that the metal, by its attraction for the ſulphur, diminiſhes a little the coheſion of this laſt with the alkali.

We quickly decompound this ſort of ſulphuret, when we add an acid to the ſolution. This immediately neutralizes the alkali, and occaſions the ſulphur and metal to ſeparate from it. While they ſeparate from the alkali, they remain combined together, and form a powder or precipitate of a deep orange or red colour, called formerly *ſulphur antimonii auratum*, now *ſulphur antimonii præcipitatum*.

In this preparation, the antimony, although it retains much the ſame principles as in its crude ſtate, is much more active however as

a medicine. The diſſolution it underwent has divided the particles far more ſubtilely than can be done by any mechanical diviſion or triture. And the cloſe union of the ſulphur and metal was diminiſhed during the combination, in conſequence of the action of the alkali on the ſulphur. The metal is therefore more diſpoſed for being diſſolved by the acids of the ſtomach, than it is in crude antimony.

But, in order to make the product of this proceſs always equal, it is neceſſary to add the requiſite quantity of acid for ſaturating the alkali, and precipitating the antimony all at once. If we add only a part, and collect the firſt precipitate before we add the reſt of the acid, the firſt and ſecond precipitates will be unequal. The firſt will contain more of the metal, and leſs of the ſulphur, than the ſecond precipitate; the attraction of the alkali being chiefly for the ſulphur of crude antimony. It therefore quits it more ſlowly than it quits the metallic part.

When we take the potaſh in its common ſtate of an imperfect carbonat, and diſſolve the antimony by it in the ſame humid way, it acts much more ſlowly and with leſs power. And when the boiled ſolution is allowed to cool, it depoſits again the greateſt part of the crude antimony which it had diſſolved, ſhewing thereby that the preſence and aſſiſtance of heat is neceſſary to enable ſuch an alkali to hold the crude antimony diſſolved.

We have an example of this in the proceſs for *kermes mineralis*.

This kermes mineralis is reckoned in France one of the capital preparations of antimony. It firſt attracted notice while it was a ſecret remedy in the hands of a Carthuſian monk, who performed ſeveral ſurpriſing cures with it in the pneumonia, and other violent fluxions or congeſtions in the lungs. Upon inquiry it appeared that the monk had got it from one Ligerie, who was poſſeſſed of the ſecret, and who had learned it from Glauber, or from a ſcholar of Glauber's. The Duke of Orleans, then regent, was adviſed by the king's phyſician to purchaſe the diſcovery of it at the king's expence, and make

it public *. But the younger Lemery, in a memoir, inſerted in the *Mem. de l'Acad.* for the year 1720, proves that this medicine was contrived, or at leaſt the proceſs for it publiſhed by his father, in his treatiſe on antimony, and that his father's proceſs is rather better than La Ligerie's. The elder Lemery called it a *ſulphur auratum antimonii*, and not improperly, for the kermes mineral, in whatever manner it be prepared, is very much, and almoſt preciſely, of the ſame nature with the *antimonium*, or *ſulphur antimonii precipitatum*, which was formerly named *ſulphur auratum* †.

Lemery's proceſs, however, and the product of it, had been neglected, until it attracted notice as a ſecret remedy, and was purchaſed for the uſe of the public, and then it became ſo much an object of attention, that the moſt celebrated French chemiſts have exerciſed their ingenuity in throwing light on the proceſs, and improving it.

A great inconvenience in La Ligerie's proceſs is, that the quantity of kermes produced by each boiling of the materials is very ſmall.

Geoffroy, who made many experiments to inveſtigate the nature of

* *Ligerie's Proceſs.*—Crude antimony broken ſmall, four ounces; deliquium of nitrate of lime, one ounce; and water eight ounces. Boil the mixture two hours. Decant and filtre it while hot. While it cools, the kermes is precipitated. Add to the remaining antimony ſix drachms of the nitrate of lime, and eight ounces of water; repeat the boiling and filtrate.——Repeat the laſt part of the proceſs; collect the three precipitates; and edulcorate with water.

† The elder Lemery's original proceſs is this.—Put into an iron pot five or ſix pounds of a ſolution of pure fixed alkali, with three or four times as much water. When the liquor boils, throw into it four or five ounces of finely powdered crude antimony. Boil the mixture a ſhort time, ſtirring it with an iron ſpatula, and then filtrate it boiling hot through paper. It will depoſit the kermes, which muſt be well waſhed, dried, and ground to a fine powder,—a gray powder remains, which is regulus which the hepar could not diſſolve. The ſame alkaline liquor may be uſed ſeveral times.

this preparation, propoſed a proceſs by which it may be obtained in far greater quantity, and with incomparably leſs trouble *.

The precipitated matter, when well waſhed and dried, is a ſoft and tender powdery matter, of a deep browniſh red, or rather a coffee colour.

The liquor from which it has been depoſited retains the greateſt part of the alkali, together with a ſmall quantity of the antimony adhering to it, but retains ſo much of the uncombined alkali, that, if boiled with more antimony, it diſſolves it again, and by cooling, depoſits a freſh quantity of kermes; and this after many repeated operations of the ſame kind.

This preparation is much the ſame with the ſulphur precipitatum. It has a moderate degree of power as an antimonial.

Meuder, a pharmaceutical chemiſt of reputation, ſays that all depoſitions by cooling, from the warm waſhings of the hepatic preparations of antimony, may be diſtinguiſhed from a kermes mineralis by the following marks:

1. The kermes is red, and the others are brown.

. Kermes act much more gently as a medicine. I may obſerve, that if the kermes be prepared by employing a cauſtic alkali, we have the *ſulphur fixum Stabelii.*

And now, having enumerated the preparations of antimony obtained by the uſe of alkalis, as well as thoſe produced by the action of heat and air, we ſhall next take thoſe produced by deflagration with nitre, which are in ſome reſpects ſimilar to thoſe already deſcribed.

* *Geoffroy's proceſs.*—Two parts of antimony, and one of alkali, are melted together and pounded. This makes an alkaline ſulphuret, ſoluble only in hot water. It is boiled with water, and filtered into a large quantity of hot water, and upon cooling, yields of kermes, three-fourths of the weight of the antimony.

In young Lemery's proceſs, fine powder of antimony is boiled with the pure deliquium of nitrate of lime; and thus the whole antimony is diſſolved.

When crude antimony is mixed with nitre, and this mixture is ſet on fire, or thrown by degrees into a hot crucible or iron pot, there is more or leſs deflagration, according to the proportion of the nitre in the mixture. In this deflagration, the acid of the nitre, by its abundant oxygen, acts moſt violently on the ſulphur, which it changes into ſulphuric acid; and the greater part of this acid combines with the alkali of the nitre. But the acid of the nitre acts alſo more or leſs on the metallic part of the crude antimony, and oxydates it either moderately, or to a high degree, according to the quantity of the nitre employed. A number of preparations made in this way have been contrived, and highly recommended, at different times. I ſhall deſcribe a few of them.

Firſt, what Mr. Lewis calls *crocus medicinalis*. A mixture of one part of nitre and eight of antimony in fine powder, is projected into a red hot crucible. So ſmall a proportion of nitre can produce no ſenſible deflagration. It ſeems only to aſſiſt the fuſion and the ſolubility of the mixture. It breaks with a glaſſy fracture, is opaque, and has a ſurface like poliſhed ſteel. It produces a maſs of a deep purple colour, like that obtained from antimony acted on by a ſmall quantity of alkaline ſalts. This preparation is alſo very ſimilar in its degree of efficacy to the alkaline ſulphuret, which was called *regulus antimonii medicinalis*; and indeed the ſame name of regulus medicinalis has been given ſometimes to this preparation alſo. It is inſoluble in water, and inſipid.

In the other preparations of this kind with nitre, larger proportions of nitre are uſed, and which produce more active effects; but the chief of them is the *crocus antimonii*, formerly named (often very improperly) *crocus metallorum. (Pharm. Lond.)* In this preparation, ſince the proportion of nitre (equal parts) is very conſiderable, the deflagration is very briſk, or rather violent; and the fuſion does not require the crucible to be red hot in the beginning; the firſt projection may be kindled by a bit of lighted paper; and by properly timing

the ſubſequent projections, the heat riſes to a great pitch, and makes the whole melt very completely. The ſaline part is ſeparated and thrown away; the vitrified metallic matter only being the uſeful part. It aſſumes a yellow colour when ground to powder, whence it has got the name of crocus. The nitre is partly converted into vitriolated tartar, and partly alkalized. If the operation is managed ſo that all ſhall be fluid at once, the greateſt part of the ſalt collects uppermoſt by itſelf. The metallic matter goes to the bottom ſemi-vitrified; but the glaſſy matter at the bottom is not perfectly free from ſalt. It contains, united with the vitrified matter, a ſmall quantity of alkaline ſalt, produced from that part of the nitre which deflagrated with the metallic part of the antimony: And, beſide this alkaline ſalt, there is even a very ſmall portion of ſulphur remaining united with the alkali and metallic oxyd. It was, therefore, ſome time ago, a practice to ſeparate as much as poſſible this ſaline matter from the crocus, by reducing the crocus to a fine powder, and boiling it in water, which (after ſubſidence) being poured off, the crocus was dried, and was named *crocus lotus*. I find the moſt ſucceſsful way of proceeding is, to deflagrate in a hot iron morter ſet on the fire, projecting very ſmall quantities, but in quick ſucceſſion. Thus you will have a good fuſion and ſeparation, and a fine crocus without further trouble. *Crocus*, or *crocus Rolandi*, according to Meuder, is the deflagrated ſtuff edulcorated without previous fuſion.

You will find great confuſion in the names of theſe productions of antimony. It was formerly called, with the greateſt impropriety, *crocus metallorum*. And you will find that the French writers, Lemery and Macquer, chooſe to call it liver of antimony,—*foie d'antimoine;* and with as little propriety, gave it the name of *crocus metallorum* after it was waſhed.

The nature of this preparation, as a medicine, is ſimilar to that of the glaſs, but rather inferior in violence.

When the doſe of nitre is much farther increaſed, beſides the com-

plete deſtruction of the ſulphur, the metallic part is more calcined; and this may be to ſuch a degree, that its operation as a medicine is thereby diminiſhed, as it becomes leſs diſpoſed to unite with the acids found in the ſtomach. Such is the *antimonii emeticum mitius* of Boerhaave, viz. antimony, one part; nitre, two parts: Such alſo is the *antimonium calcinatum*, (Lond.) viz. antimony, one part; nitre, three parts. The matter at firſt taken out of the crucible contains ſulphat of potaſh, and a little unſaturated alkali. Theſe ſalts are ſeparated by hot water, and then we have the pure white oxyd. Four ounces of antimony yield five and a half ounces of the *antimonium diaphoreticum lotum Meuderi*, which is accordingly called *antimonium calcinatum;* as alſo *antimonium diaphoreticum* *.

The *antimonium uſtum cum nitro* of the Edinburgh Pharmacopœia may be conſidered as ſimilar to theſe preparations, only more active than the antimonium calcinatum. The crude antimony is firſt roaſted to a calx; then mixed with an equal quantity of nitre, and melted, or made red hot one hour; and then edulcorated with water. It was meant to be an imitation of James's powder; the proceſs being copied from the ſpecification of his patent. But either Dr. James changed his proceſs afterwards, or gave a falſe or diſguiſed deſcription of it; for lately it has been clearly proved to be very different, by Dr. Pearſon's experiments, read to the Royal Society of London, in 1791, and publiſhed in the Philoſophical Tranſactions. It now appears to be a combination of antimony with the acid of phoſphorus, or rather with a phoſphat of lime. Nitrous acid diſſolves the phoſphat; and the phoſphoric acid remaining in the ſolution is eaſily diſ-

* Geoffroy obſerved a ſingular phenomenon in his operations on this medicine. Having ground an ounce of it with two ounces of black ſoap, he roaſted the mixture to a coal, and then ground it coarſely with another ounce, and expoſed it to violent heat, in a covered crucible. Five hours after all was cold, he took off the cover. The mixture inſtantly took fire; and being very ſpongy, ſo that the air had eaſy acceſs to the interior parts, it took fire all over, and diſſipated with a terrible exploſion.

covered, by means of a ſolution of mercurial nitrate, or by a nitrate of lead. The antimonial oxyd is diſcovered by means of muriatic acid, and precipitation from it by water.

Dr. Pearſon's judicious examination led him to attempt the preparation, on the principles ariſing from this analyſis; and his imitation is ſo undiſtinguiſhable from Dr. James's powder, that it is adopted by the London and Edinburgh Diſpenſatories, under the name of *pulvis antimonialis*, or *antimonium calcareo-phoſphoratum*. Equal weights of antimony and horn ſhavings are calcined till of a very fair gray colour, and then kept red hot in a coated crucible, for two hours; and when cold, reduced to a fine powder, which, when well prepared, is of a pure white, or has a ſlight caſt of yellow, but not inclining to brown.

Preparations with Acids.

In general, the acids do not act ſo well on crude antimony as they do on the regulus, or pure metallic part of it. The ſulphur, in ſome meaſure, protects the metallic matter, but not to ſuch a degree as to prevent entirely the action of the foſſil acids, nor even ſome weak action of the vegetable acids. I ſhall now deſcribe the preparations made with acids applied to antimony in different ſtates. And firſt, with the

Sulphuric acid.—There are no preparations with this acid in either of our pharmacopœias. A Dr. Klaunig of Breſlaw, in a book entitled *Noſocomium Charitatis*, recommends the following: Diſtil vitriolic acid from antimony ſeveral times. By doing this the metallic part is oxydated by the acid, and combined with a part of it; and the ſulphur is, at the ſame time, ſeparated by ſublimation. After which, the ſulphat of antimony is taken out of the retort, ground to powder, and ſome alcohol burned on it. It is a medicine, of which two grains work gently, by ſtool, and vomit, and ſweat. And he recommends it ſtrongly for quartans. Wertholfs (in his *Obſ. de Febribus*) teſtifies

that it is emetic, and purgative, and diaphoretic. Wilſon's *antimonium catharticum* is probably of the ſame nature. Wilſon calls it an infallible purge, and ſays that he knew three poxes cured by it. They were probably ſome cutaneous diſeaſes which he miſtook for pox.

There are no preparations obtained by the action of nitric acid upon crude antimony; unleſs we chooſe to conſider the *bezoardicum minerale* as ſuch, in ſome meaſure: But it is different, as I ſhall mention preſently.

The muriatic acid, aſſiſted with a little nitric acid, or in form of aqua regia, diſſolves the metal, and leaves the ſulphur. It therefore thus forms a ſolution of the metal, that is quite the ſame as if the pure metal had been uſed. And the corroſive muriat of quickſilver, on account of the abundance of muriatic acid and oxygen it contains, can alſo be made to act on the metal in ſulphuret of antimony, as well as upon the metal in its ſeparate ſtate. The muriat of quickſilver and the ſulphuret of antimony being mixed together in powder, and diſtilled in a retort, a corroſive muriat of antimony ariſes; and the quickſilver unites with the ſulphur, and remains in the retort, in the form of a black ſulphuret of quickſilver, which, if the heat be very much increaſed, ſublimes into the neck of the retort, in the form of cinnabar. To this cinnabar the chemiſts give the name of *cinnabar of antimony*. This was the proceſs moſt commonly practiſed for preparing the *antimonial cauſtic*, or *corroſive muriat of antimony*.

But the London college of phyſicians, learning probably that the chemiſts had another method, much cheaper, and which is as good, have adopted it in the laſt edition of their pharmacopœia. This is, to form the muriat of antimony directly, in the ſame, or nearly the ſame way, as was practiſed for corroſive ſublimate. Equal quantities of vitriolic acid and antimonial crocus are mixed with a quantity of common ſalt equal to their ſum, and treated in the diſtilling apparatus. I refer you to Mr. Ruſſel's own account of the proceſs, given in the firſt volume of the Tranſactions of the Royal Society of this place.

It may alſo be effected by the oxygenated acid, as it is formed by diſtilling the ordinary muriatic acid from the black oxyd of manganeſe. But Mr. Ruſſel's proceſs is much better. Scheele's proceſs is not very different.

I obſerved before, that this antimonial cauſtic, or muriat of antimony, is extremely corroſive. On account of its extreme acrimony chemiſts ſtudied how to render it milder. The moſt ſimple way is, by adding to it plenty of water. The greater part of the acid is thus immediately ſeparated. A ſmall portion remains adhering to the metallic calx, and precipitates with it, in the form of a white powder, called *pulvis Algerothi*, from Victor Algeroth, or Algarotti, formerly a phyſician at Verona, who called it *pulvis Angelicus*. It is an oxyd very moderately oxydated, and which ſtill retains, as I already obſerved, a very ſmall portion of the acid combined with it; and on both theſe accounts, is very ſoluble in more acid, and alſo very fuſible. It melts moſt eaſily into a tranſparent yellow glaſs. Mr. Macquer, and others, will have it to be a pure calx, totally free from acid; but in this I am perſuaded they are miſtaken. Its fuſibility is a proof. It diſſolves readily in vegetable acids, and in ſolution of ſal ammoniac. It is recommended by Dr. Saunders in this form as a good application to ill-conditioned ulcers; and alſo as a milder internal medicine.

Bezoardicum minerale may alſo be conſidered as a mitigated muriat of antimony. The preparation of this drug ſeems to me a proceſs which has been undertaken very much at random, juſt to ſee what would reſult from it.

To four ounces of butter of antimony twelve or ſixteen of nitrous acid are added, by two ounces at a time. Violent fumes and ebullition, or efferveſcence, are immediately produced, which muſt be carefully avoided, they being extremely acrid or corroſive. The efferveſcence is leſs at each ſubſequent addition. When all is quiet, the whole is diſtilled to dryneſs, and the reſiduum in the retort is the bezoardicum minerale.

The firſt efferveſcences are chiefly an oxygenated muriatic acid; and the nitrous acid does not riſe till ſome time after. This is not the uſual opinion; and it is even thought that this preparation is nearly the ſame with diaphoretic antimony, or a perfect white oxyd. It may not be impoſſible to bring it to this ſtate; but in my own experiments, as well as in the examination of ſuch ſpecimens as I was well aſſured that they had been prepared from butter of antimony, I found it to be ſtill a *muriat of antimony*. I believe indeed that the antimonium diaphoreticum is often ſold for it, being a much cheaper preparation; and, when made with impure nitre, it may be intrinſically the ſame. But I have not found that any number of abſtractions of pure nitrous acid will free butter of antimony completely from muriatic acid. The miſtake, if any, is of little conſequence in medicine. But it is perhaps a more difficult matter to explain or account for the deoxygenation of the muriatic acid by means of the nitric, which we know to be the ſpeedieſt means to oxygenate it. We muſt conſider it, not as a deoxygenation of what part of the acid remains combined with the antimony, but as a *ſuper-oxygenation* of what is expelled from it. The efferveſcence is violent, and the fumes are uncommonly corroſive. We know that the acid combined in the antimonial muriat is in its oxygenated ſtate. The metal, already ſaturated with oxygen, cannot decompoſe the nitric acid, and thereby occaſion the fumes of aqua regia. It is decompoſed by the naſcent muriatic acid; and this comes off in a ſuper-oxygenated ſtate. There are two or three other proceſſes in which this rare acid is formed in the ſame manner.

The only remaining ſaline preparations are thoſe produced with the vegetable acids. The *antimonium tartariſatum*; (Edin. and Lond.) The *vinum antimonii tartariſatum*; (Edin. and Lond.) and the *vinum antimonii*. (Lond.)

The vegetable acids do not act ſenſibly upon crude antimony, and but weakly on the pure antimony. To facilitate their action, we

muſt take the metal, not only ſeparated from the ſulphur, but moderately oxydated, or reduced to its moſt ſoluble ſtate. Accordingly, the compounds of it with the vegetable acids were formerly ordered in our diſpenſatories to be prepared either with the waſhed crocus, or the vitrum antimonii: But the crocus was formerly in moſt general uſe for this purpoſe, (and it is ſtill uſed at London), until complaints prevailed every where of the weakneſs, inefficacy, and inequality of the emetic tartar. This was occaſioned by frauds in preparing the crocus, uſed much for horſes, &c. The great demand for it encouraged the druggiſts to attempt cheaper preparations; and inſtead of employing the crocus antimonii lotus, as was directed by the pharmacopœia, which is made by deflagrating equal quantities of nitre and crude antimony, they uſed only half, or three parts, and even leſs, of the nitre, the moſt expenſive article; and to ſucceed the better in bringing the mixture into thin fuſion, ſo as to make a uniform glaſs, they employed a little alkali. The reſult of all this is a preparation nearly the ſame with the regulus medicinalis; a drug almoſt inactive, and inſoluble. If the weakneſs of this preparation were all its imperfection, it could eaſily be remedied by increaſing the doſe. But, by thus ſtinting the nitre, it is almoſt impoſſible to make a uniform maſs; and different portions of the ſame lump will often be in different ſtates. This ſpurious crocus may be eaſily diſtinguiſhed from the true by its colour. In the maſs the ſpurious is opaque, and almoſt black; and when reduced to fine powder, it is of a dirty purple colour. The genuine is liver-coloured in the maſs, and a deep yellow when finely powdered.

Now the ſtate of the crocus is moſt conſequential for the preparation of emetic tartar; for a large quantity of the nitre is neceſſary for deſtroying the ſulphur, and then bringing the metal into that ſtate of moderate oxydation that renders it moſt ſoluble in the weak acids. Leſs nitre will leave ſome ſulphur, which ſheathes the metal; and the

pure regulus has little ſolubility in the vegetable acids, and requires a little previous oxydation.

In conſequence of theſe frauds in preparing the crocus, the emetic tartars and wines, as prepared by different apothecaries, were widely different in ſtrength, and often totally diſappointed the practitioner.

Different chemiſts have exerted themſelves to remedy this inconvenience in a medicine of ſo much activity and importance,—indeed the moſt valuable of the antimonial medicines; and in conſequence of their experiments, and of what has been publiſhed on this ſubject, the *tartrite of antimony*, or *antimonium tartariſatum*, is now always made, I believe, ſufficiently ſtrong.

One of the beſt proceſſes they recommended, and which was lately the proceſs of the Edinburgh Pharmacopœia, was to uſe the vitrum antimonii, which is preferable to crocus, becauſe we have no experience yet of any miſtakes or frauds committed with regard to it, and we can always know if it be good. We are there directed to beat it to very fine powder, and mix it with an equal weight of the cryſtals of tartar, alſo powdered. In the next place, for every ounce of the mixture, or half ounce of tartar, take one pound of pure water, (diſtilled water is the beſt), and ſet it in a furnace to boil. As ſoon as it boils, throw in the mixture of tartar and vitrum by degrees, until all is in; and continue to boil gently for ſeveral hours. The number of hours neceſſary cannot be ſpecified with preciſion. It depends upon the degree of pulverization of the vitrum. If it be a very fine and almoſt impalpable powder, about four hours, or even leſs: If not ſo fine, twelve hours. It is more neceſſary to attend to this, when the vitrum is employed, than when we employ the crocus. The firſt, being powdered mechanically, can never be ſo impalpably levigated as the crocus, which falls a ſoft powder, completely divided by the ſeparation of the ſaline matter. Beaumé, in examining the preparations of eminent apothecaries, found differences in the quantity of metal obtainable from an ounce of the tartarized antimony, which were ſurpriſingly great. In ſome he found 150, and in others

ſcarcely 40 grains. Vinum emeticum may alſo differ in conſequence of a difference in the acidity of the wine.

I need ſcarcely inſiſt on the neceſſity of much water and a boiling heat. We know that water diſſolves only one-twenty-fourth of its weight of tartar with a boiling heat, and that it lets go a great portion of this by a moderate diminution of its heat.

Mr. Macquer would preſcribe the mercurius vitæ in preference to the crocus or glaſs, as more to be depended on for perfect uniformity. But I do not ſee reaſon to doubt of the goodneſs of theſe preparations; and by preſcribing ſo coſtly a thing as mercurius vitæ would only occaſion more ſubſtitutions or adulterations.

Beaumé has further given a caution with regard to the veſſel in which the mixture is boiled. He ſays it muſt neither be iron nor copper. He finds that theſe veſſels decompound the emetic tartar in ſome meaſure. The veſſel muſt be glaſs, or ſilver, or earthen ware not glazed with lead. But M. de la Caille aſſures us that iron may be uſed.

When the operation is conducted in this manner, the tartar is ſaturated with the antimonial calx, part of which remains undiſſolved. And the liquor being filtrated affords, by evaporation, fair cryſtals, pyramids of three ſides,—tranſparent while wet, but becoming white and opaque in the air. And theſe cryſtals are the ſaturated tartrite; and are powerfully emetic. The doſe is from one grain, or one-half, to two, or three at the utmoſt, for an emetic. This may ſeem an inconvenience, but it is eaſily remedied by mixing ten grains, for inſtance, with three or four times as much ſugar; and thus we will have a powder which it will be eaſy to weigh out in moderate doſes: Or a more common way is to dilute it in water,—three or four grains, for example, in ſix ounces; and a ſpoonful is taken every half hour until it operate.

But beſide the vitrum antimonii, any other preparation in which the metal is freed from the ſulphur, and very moderately oxydated,

may be employed to ſaturate the tartar, and produce a medicine equally powerful and certain.

To complete this article, Dr. Saunders added a ſimple and uſeful method of examining emetic tartar, ſo as to judge if it be properly prepared, and as ſtrong as poſſible, or what degree of ſtrength it poſſeſſes. On examining the ſolubility of different tartars, he found, by experiments, that they are more ſoluble in proportion as they are more completely ſaturated with antimony; and that the difference among tartars in this reſpect is ſo conſiderable, that it is eaſy to diſtinguiſh them. Thus, one ounce of water, at a middling temperature, diſſolved,

Of the ſaturated tartar	52 grains.
Apothecaries' hall	38
A London chemiſt's	32
Edinburgh ſhops	leſs.

I only wiſh he had ſpecified the degree of heat more particularly.

The next ſet of preparations we have to mention are the *reguli*, and preparations from them.

The proceſs by which antimony is obtained in the largeſt quantity and pureſt, is ſimilar to that followed in extracting other metals from ſulphurous ores, viz. evaporation of the ſulphur by uſtulation, and reduction of the calx. But other proceſſes have been commonly followed: Theſe have in general been two. The proceſs for ſimple regulus of antimony, and that for martial regulus of antimony.

For the ſimple metal, or what is called ſimply *regulus of antimony*, the crude antimony is melted with about half its weight of black flux, or rather the ingredients for producing black flux, viz. nitre and tartar, which occaſions part of the regulus to ſeparate; the hepar ſulphuris formed by the alkali and ſulphur, having rather more attraction for the charcoal of the black flux than for the metal. But this ſuperiority of attraction is not ſo great as to occaſion a complete ſeparation of the antimony. Part only ſeparates. The reſt re-

mains diſſolved in the ſaline ſulphurous ſcoria, and forms with it a hepar antimonii, and is employed as ſuch in the London Pharmacopœia.

The other proceſs which I ſaid is alſo often followed, is that for *regulus antimonii martialis*. Crude antimony and iron filings, or ſmall nails, in equal parts, are mixed and melted with a violent heat, and commonly with addition of a ſmall quantity of nitre or fixed alkali. In this operation, the ſulphur ſhews a ſtronger attraction for the iron than for the antimony, and forms with the iron a hard ſulphurous compound. The antimony ſinks ſeparate in large quantity, but not ſo pure as by the former proceſs. It diſſolves ſome of the iron. It is purified by crude antimony, and two or three meltings with a little nitre. The ſulphur of the crude antimony forms a ſcoria with the iron, and floats above; and thus the regulus is freed from the iron. Melting again with nitre deſtroys the ſulphur brought in by the crude antimony, and not carried up by the iron. Thus it may be made as pure as the other. Many other metals can alſo be uſed, all except gold, zinc, and platinum, having a ſtronger attraction for ſulphur than antimony has *.

In whatever manner the antimony be ſeparated from ſulphur, if it be made very pure, and caſt into a conical veſſel, it exhibits a ſtar. *Regulus antimonii ſtellatus*,—*regulus ſtellatus*. Many myſteries have been ſuppoſed to be indicated by the figure which the ſurface of this metal aſſumes in cooling, it having generally a ſtellated or radiated figure,—this is owing to its mode of cryſtallization, combined with the

* Lehman relates a very ſingular experiment made with antimony and arſenic, which being diſtilled together, with a violent heat, yield a ſulphurous ſublimate, which does not deflagrate with nitre; and he ſays that a regulus of antimony remained in the retort. I found this reſiduum not diſtinguiſhable from a regulus by its chemical properties, but very diſtinguiſhable from it by a beautiful changeable colour upon the facets of the metal when broken. I attributed this to a film of arſenic, which being tranſparent, ſhould exhibit ſuch colours. But no trial that I could put it to ſupported my conjecture. The ſublimate did not deflagrate, but burnt ſlowly with a dull heat. EDITOR.

progreſs of cooling, which proceeds from the ſides of the veſſel to the centre. It is needleſs to take up your time with proving the folly of theſe fancies.

Preparations from the Regulus.——*Ceruſſa antimonii; ſtomachicum Poterii; cardiacum Poterii; antihecticum Poterii; tinctures of antimony*

Uſes of Antimony.——It affords, in many of its preparations, medicines of great efficacy to remove many diſeaſes of the human body, as well as of other animals.

In the arts, it is uſed for refining gold,—and the regulus is mixed with tin and lead to harden them, for the compoſition of pewter; but I apprehend that the greateſt quantities are employed to mix with theſe metals for letter founding. In this compoſition, great hardneſs, and great fuſibility, are important properties. It is alſo peculiarly fortunate, that the latent heat neceſſary for the fluidity of this compoſition is very moderate, ſo that a man can work without intermiſſion, when the letters are ſmall. The mould loſes ſo much heat while opening to ſhake out the letter and ſhutting again, that the next letter makes no accumulation of heat. Were it otherwiſe, the mould muſt be cooled after a few letters, and the expedition of the work greatly diminiſhed.

GENUS VI.—ZINC, OR SPELTER,

Another brittle metal, or ſemimetal, bears ſome reſemblance to the laſt. Like it, it ſhews a plated texture when broken. But it is eaſily diſtinguiſhed. 1*ſt*. It is not ſo brittle, but can be compreſſed by the ſtrokes of a hammer; and even bears ſome degree of extenſion under the hammer. It bears extenſion by rollers very well, and can thus be drawn into very thin plates, if carefully annealed between the operations. It alſo bears drawing in the wire-plate. It has therefore more coheſion, and is more difficultly broken to pieces. The plates are not ſo broad, and its colour inclines to bluiſh, when compared with the

other two. It is the moſt expanſible of all the metals by heat. It melts before it begins to grow red hot, and flows quite thin at 680. When melted and poured into a veſſel, it may be reduced to a pretty fine powder by ſimple agitation. Its ſpecific gravity is nearly 7,2. It has ſome ſingular properties relative to its ſolid form. This imperfect ductility is accompanied by an odd kind of toughneſs, which makes it extremely difficult to work it in the ordinary way, by filing it. It ſticks in the files; and ſoon renders them uſeleſs. Lead, though a much ſofter metal, has not this quality. Pure copper has a little of it. It ſticks in like manner to the edges of the cutting tools, with which it is ſcraped or turned in the lathe,—and what is ſtill more ſingular, when mixed with copper which has the ſame quality, it forms a metal which the workmen find to work more pleaſantly than any other metal. Moreover, although annealing it, after every paſſage through the flatting mill enables it to extend much more than it would otherwiſe do, yet if it be hammered in its hot ſtate, it crumbles to pieces with the greateſt eaſe.

If the heat be further increaſed to a vivid red or white heat, in cloſe veſſels of proper form, ſuch as an earthen retort and receiver, the whole ariſes in vapour, which, in cloſe veſſels, may be condenſed again without further change. But when the ſame heat is applied in the open air, it ſuddenly takes fire like an inflammable body, and burns rapidly, with a bright and dazzling flame, and the metal is quickly changed into a calx. This is very white, and ſoft, and rarefied, in compariſon with other metallic calces. The greater part of this calx is accumulated in the veſſel, juſt over the burning zinc, and ſoon impedes the further action of the air on the remaining zinc; but ſome part of it riſes up into the air, and floats or flies about in it like cobwebs. In this ſtate it was called *pompholix*, and *philoſophic* wool, alſo *nihil album*. This, therefore, is the moſt expeditious method of calcining zinc. The proceſs deſcribed in the Edinburgh Pharmacopœa is this: "Place a large or deep crucible, or other deep

" earthen veſſel, in a melting furnace, inclined a little towards the " door. When heated to the proper degree, let the zinc be thrown in- " to it in ſmall pieces, waiting till the firſt is entirely burnt before the " ſecond is thrown in. Thus the oxyd of the zinc is accumulated in " the crucible; and being light and bulky, it muſt be ſtirred now and " then with an iron rod, that the air may be admitted to the burning " metal: And when a quantity of it is accumulated, it muſt be taken " out with an iron ſpoon before any more of the zinc is thrown in."

The late Profeſſor Gaubius of Leyden, who recommended this oxyd to phyſicians as an uſeful remedy for convulſive diſorders, deſcribed a different way of preparing it, but not ſo good.

From theſe phenomena, it is evident that this metal is one of the moſt calcinable of any, when it is expoſed to a violent heat; and it is reaſonable to conclude, from the great brilliancy of its flame, and the great heat which its inflammation produces, that in its calcination it attaches to itſelf a very great quantity of oxygen. But it has not a diſpoſition to attract oxygen eaſily from the atmoſphere, and to calcine by means of humidity, without the aſſiſtance of heat, in which it differs from iron and moſt other metals *.

The oxyd of zinc is ſo unfuſible, becauſe it is probably more highly calcined than the fuſible oxyds of ſome other metals. It is, however, in ſome degree fuſible in a very violent heat, and forms a fine yellow glaſs.

The reduction of this oxyd was long a difficult problem. It was

* It is not altogether inactive in this reſpect. Its poliſh is very eaſily tarniſhed by expoſing it to very damp air; and if wetted, and kept in that ſtate an hour or two, its poliſh is entirely taken away, and it becomes of a dull leaden colour. When viewed in this ſtate with a microſcope, we ſee it evidently corroded; but I have not obſerved this to increaſe by length of time. This is ſurely an oxydation, or ruſt. It ſeems completely to cover the ſurface, rendering it neutral or ſaturated, and this defends the interior parts. But if the metal be made nearly red hot, and water be ſprinkled on it with a bruſh, it then acts powerfully on the water, decompounds it, and produces much hydrogenous gas. Zinc is oxydated in this way, juſt as iron is.

EDITOR.

found ſo difficult, that many ſuppoſed it impoſſible; but this proceeded from the improper manner of attempting it. They tried it in the manner uſually practiſed with other metals, by mixing the oxyd in a crucible with black flux, or with charcoal and ſalts. In this way the heat which was neceſſary for the reduction, was ſufficient for totally evaporating the metal as ſoon as it was formed. It was therefore all loſt.

Mr. Margraaf, attending to this, firſt contrived to accompliſh the reduction. He mixed the oxyd with one-eighth of its weight of powdered charcoal, or lamp black,—introduced the mixture into a ſmall earthen retort luted to a receiver, and urged it with an intenſe white heat. He thus got zinc again in the form of a metallic ſublimate, or maſs, attached to the neck of the retort; and he found it rather more malleable than ordinary zinc.

The ſame expedient occurred to Neuman, but he tried too ſmall a quantity, (two drachms) ſo that the air incloſed was ſufficient to burn the zinc again; and he got nothing but half burnt flowers in the neck of the retort, which ſhewed, unqueſtionably, that they had been once reduced, otherwiſe the calx would never have been ſublimed.

Zinc is eaſily diſſolved by all the acids, and is united with them by a very ſtrong attraction. The acids are therefore more neutralized by it than by moſt other metals, and the compounds do not eaſily ſuffer any ſeparation of the acid from the metal by large dilution with water.

The ſulphuric acid even requires to be diluted conſiderably with water, to make it diſſolve the zinc well, juſt as in diſſolving iron. And further, the zinc, while diſſolved by this acid, decompounds a part of the water, as iron does; and a great quantity of inflammable air is, in conſequence, produced during the briſk effervescence with which this diſſolution is performed. One ounce of zinc produces 356 ounce meaſures with one ounce of ſulphuric acid. One ounce of iron gives 412 of air with 2 ounces of the acid. The metal is

therefore oxydated as well as diſſolved, but receives all the oxygen from the water. The compound of oxydated zinc and ſulphuric acid thus formed is eaſily cryſtallized, and gives cryſtals that are not deliqueſcent. They are an article of the materia medica, and were named formerly *white vitriol*;—in the new language of chemiſtry, *ſulphat of zinc*.

The nitric acid, in the diluted ſtate of aquafortis, diſſolves this metal with the greateſt violence and rapidity, and becomes exceſſively hot. In the violent efferveſcence which attends this diſſolution, the acid ſuffers a great and violent abſtraction of its oxygen, and all the changes which are neceſſary concomitants of ſuch abſtraction. Part of it is therefore changed into red vapours; a great part into nitrous gas; another part into the leſs oxydated nitrous gas, which I lately deſcribed; and laſtly a part into pure azote.

By ſome variations in the manner of diſſolving the metal we can modify theſe changes of the acid. If, for example, the aquafortis be largely diluted with water before it be applied to the metal, the gas produced is almoſt totally the leſs oxydated nitrous gas, or dephlogiſticated nitrous gas of Dr. Prieſtley.

The muriatic acid, in its common ſtate, alſo diſſolves zinc eaſily, with efferveſcence and production of a great quantity of inflammable air. But when applied in its oxygenated ſtate, there is no inflammable air produced. The reaſon is obvious. The zinc is ſupplied with oxygen, which was very looſely combined with the acid. This muriat of zinc does not give cryſtals eaſily. It is a deliqueſcent compound. The ſolution of it, mixed with glue, or employed to diſſolve it, forms a compound which does not become dry in the air, but has the inviſcating quality of birdlime. This birdlime would probably be the beſt for catching birds and inſects for the natural hiſtorian, as it would eaſily be waſhed off from the feathers of birds, or limbs of inſects, by water.

The vegetable acids act alſo on zinc without difficulty and ſome

inflammable air is produced during their action. The oxyd of zinc alſo diſſolves in all the acids, but without effervescence. A ſaturated ſolution in the acetous acid is a liquor very like olive oil.

The alkalis act on zinc as upon ſome other metals. Applied to it in its metallic ſtate, they corrode it in ſome meaſure. Applied to it in the ſtate of oxyd precipitated from acids, they in ſome caſes diſſolve it. Volatile alkali is thought to act on it in a peculiar manner. When powdered zinc is put into a ſolution of the cauſtic volatile alkali, it yields, after a long time, inflammable air. This, however, ſeems rather to come from the water than from the alkali. Did it come from the alkali, we ſhould alſo obtain azotic gas, which I have never been able to diſcover by this treatment.

Such of the compound ſalts as act on other metals, act more readily upon zinc, which in conſequence of its inflammable nature, produces remarkable effects on them, ſimilar to thoſe produced by the inflammable bodies. Thus, melted with ſulphat of potaſh or of ſoda, it changes them into alkaline ſulphuret, and is changed itſelf into an oxyd: And with the ſalt of urine, or phoſphoric acid, it yields phoſphorus. It alſo decompoſes ſal ammoniac, by grinding them together, as appears by Margraaf's experiments, which I mentioned when delivering the theory of lime. This is unqueſtionably owing to its very ſtrong attraction for acids, which is ſuch, that alkalis decompound the nitrate of zinc with difficulty. To the ſame cauſe we may aſcribe the decompoſition of alum by boiling it with zinc. If the ſal ammoniac and zinc be treated in the way of diſtillation, we obtain firſt an incondenſible ſuffocating alkali,—then a volatile muriatic acid, in thick white fumes,—in an open fire, white flowers ſucceeded; and at length, a reddiſh and a black butter.

Nitre deflagrates violently with zinc; but it muſt be heated ſo hot that is not eaſy to diſtinguiſh its deflagration with the nitre from the inflammation to which it is ſo much diſpoſed of itſelf. Its flowers do not ſenſibly deflagrate, yet they alkalize double their weight of

nitre. The fixed alkali and calx form together a maſs externally greeniſh, internally purple. Infuſed in water, the alkali diſſolves, and with it a part of the calx, tinging the water purple *.

Zinc does not unite with ſulphur, nor hepar ſulphuris, nor with crude antimony, and is therefore purified by the action of ſulphur from admixtures of lead, which it frequently contains. Alkaline and calcareous ſulphurets, however, readily unite with the calx and diſſolve it, forming a ſubſtance reſembling its ores.

None of the earths have been obſerved to have any remarkable effect on zinc or its calx.

It unites with all the metals except biſmuth and nickel. It is indeed difficult to combine it with iron, becauſe the great heat that is neceſſary diſſipates the volatile metal, and it carries off ſome iron with it. It has ſomewhat of this effect on all the more calcinable metals. Moſt of theſe mixtures boil and deflagrate more than zinc alone, and globules of the metal are frequently ſcattered about. Hence it is called *metallic nitre*. Copper is but little affected this way, and the *cadmia fornacum* of the braſs-founderies rarely contains any copper. When they are melted ſeparately, and then mixed, there is frequently a violent detonation, and much of the metal is thrown about. When lead is added to melted zinc, the mixture takes fire, and the zinc burns away. They mix quickly, when the zinc is added to melted lead. Arſenic makes it black and friable.

United with mercury in the form of amalgam, it is the moſt powerful exciter of an electric globe. The beſt proportion is four parts of mercury to one of zinc.

Mixed with tin, in a ſmall portion, it greatly increaſes it hardneſs,

* With reſpect to the other neutral ſalts, the only remarkable effect that I know, is the formation of a butyraceous ſublimate of zinc, like the muriat of antimony, by diſtilling common ſalt and the ſulphat of zinc, or by ſubliming the ſolution of zinc in the oxygenated muriatic acid. EDITOR.

and improves its colour, making it like ſilver; but this mixture is more apt to be corroded by acids. It is uſed however in the manufacture of pewter.

Mixed with lead in the proportion of one to twelve, or even leſs, it improves its tenacity in a moſt ſurpriſing manner, making it four or five times ſtronger. It would therefore be a great improvement on water pipes.

The moſt uſeful mixtures of zinc are thoſe with copper, in various proportions. It communicates a yellow colour, notwithſtanding its own whiteneſs, and it removes the diſagreeable toughneſs which makes copper ſo difficult to work with the file and in the lathe, while it very little impairs its tenacity and ductility. In a very large proportion to the copper, it makes the *hard*, or *ſpelter-ſolder*, uſed for copper, braſs, and iron. In a ſmaller proportion, it makes braſs; and in other proportions it makes more or leſs perfect imitations of gold. Such are *pinchbeck*,—*princes metal*,—*ſimilor*,—*Bath metal*,—*tutenag*, &c. Homberg, Geoffroy, Hellot, and Lewis, have made many experiments and uſeful obſervations on theſe mixtures; and to their writings I refer you for farther information on this head. Obſerving, in general, that all theſe mixtures loſe ſome of the zinc by evaporation in great heats, and that long continuance of it will expel the whole. This is owing both to the volatility and to the inflammability of the zinc. You will always obſerve an uncommon brightneſs on the ſurface of the melted metal, greater than that of the ſurrounding fuel. This is juſt a low flame, not one-tenth of an inch high.

It remains only to mention the operations by which it is extracted from its ores.

For a long time, all the zinc uſed in Europe was imported from China, except a ſmall quantity which was obtained in the Hartz foreſt in Germany, from an ore which yielded lead, and copper, and ſilver, and a little gold at the ſame time. We have not been inform-

ed how the Chineſe zinc is obtained. The proceſs by which the German was got was a little uncommon.

In the ſide of the furnace, (which is a reverberatory) oppoſite to the bellows, the wall is double, conſiſting of two thin fire ſtones, with a hollow between. On a level with the uſual ſurface of the melted metal, there is a chink opening into this cavity. The zinc evaporates as faſt as it is formed; and the vapour is driven into this hollow through the chink by the blaſt of the bellows. The ſide of the cavity, which is in contact with the air of the hut, is cool in compariſon with the reſt, the ſtone being thin and being often ſprinkled with water. Here, therefore, the ſublimed metal attaches itſelf, while the flowers, which are unavoidably formed by the calcination of part of this metallic vapour, riſe farther up, and get into the long funnel, where they collect, and are got out from time to time by the name of *cadmia fornacum*, *Tutia*, *diaphryges*.

This very ſingular proceſs was the contrivance of a common ſmelter, who had obſerved this ſtrange metal collecting in the retired corners of the furnace, at Rammelſberg. It is certainly ingenious, and ſhewed a ſagacious and intelligent mind. Such have been moſt of the proceſſes in metallurgy; and it is by a collection of theſe caſual arts that our ſcience has ariſen. The quantity thus got was but very ſmall; and no other method was known or attempted in Europe for producing this metal, although its ores, which are very plentiful, appear to have been ſufficiently known as ſuch from their effect in making braſs.

In the greater part of theſe ores, the zinc is in the ſtate of a calx; in conſequence of which, they appear more like ſtones than metallic minerals; and were actually conſidered by many as a particular ſpecies of ſtone or earthy matter, and called *lapis calaminaris*. The original name, however, by which it was known to the ancients, and mentioned by Pliny, was that of *cadmia*.

Sometimes it is in a leſs calcined ſtate, which gives it more or leſs

metallic opacity and luſtre; and in ſome caſes there is ſulphur in its compoſition, which produces the ſame effect. It is then called *black Jack*, by the Engliſh miners; by the Germans, *blende;* and by natural hiſtorians, *pſeudo-galæna,—i. e.* mock-lead ore.

This ore is ſomewhat curious. It is tranſparent when pure; and in a very ſtrong light, although ſeemingly opaque, it tranſmits a very deep brown light. It breaks alſo with a glaſſy fracture. Notwithſtanding theſe marks of being homogenous, a bit of it, ſlowly diſſolved in weak aquafortis, leaves a ſpongy maſs, which retains the original ſhape completely, and this weighs about one-fifth or one-ſixth of the blende. It is pure ſulphur, not chemically combined.

Theſe ſeveral varieties of it have been long employed for making of braſs. The proceſs conſiſts firſt of roaſting; then cementation with charcoal and copper. The copper fixes the zinc, and acquires the yellow colour.

This was the only uſe made of the ores of zinc in Europe; and the manner in which they produced their effect was not thoroughly underſtood, until Mr. Margraaf extracted zinc from them, without the aſſiſtance of any other metal. But now, in conſequence of his diſcovery, manufactories of zinc have been eſtabliſhed in England, and elſewhere.

The Engliſh proceſs is what the chemiſts call *deſtillatio per deſcenſum*. The ore, mixed with charcoal, is put into conical pots, having in the bottom an iron pipe, which paſſes through a hole in the hearth of the furnace, and reaches to the mouth of a rude receiver containing water. Fuel being kindled around the pots, (whoſe mouths are ſtopped with clay) and care being taken that it ſhall not be ſo hot as to melt their contents, the metallic vapours are expelled downwards, and condenſed in the receivers.

But lapis calaminaris is ſtill much more uſed for making braſs, the proceſs for which is the cheapeſt way of extracting the zinc, while by the ſame fire it is alſo mixed with the copper. The ore being cleared from ſulphur, and other impurities, by roaſting, is ground and mixed

with charcoal. The mixture is put into pots, and ſtratified with plates of copper. A proper heat being given, the ore is metallized, and the metallic vapour is immediately ſeized on by the copper,—renders it more fuſible, and melts down with it, and lodges in the bottom of the pot, where it is defended from the air by the vitrified ſlag floating above it. When the proportion is properly hit, the copper gains an addition of one-third of its weight, in becoming braſs.

Although copper fixes zinc to a certain degree, it does not entirely prevent its evaporation and calcination in ſtrong heats. Hence when braſs is melted, if it be expoſed to air, it is liable to loſe part of the zinc, and by repeated fuſions, the whole. Hence *cadmia fornacum*,—*pompholix*,—*diaphryges*,—*nihil album*,—*tutia*, &c. which are different names for the condenſed vapours which eſcape from the furnaces in theſe proceſſes for braſs.

Uſes of Zinc.—It is chiefly uſeful for metallic compounds,—braſs,—pinchbeck,—pewter,—for tinning,—and for ſolders; and it is an uſeful article of the materia medica.

Until lately, zinc was hardly ever uſed internally; except ſometimes the white vitriol was uſed as a vomit of quick operation. It was chiefly confined to external uſe. It poſſeſſes uſeful powers as an aſtringent and repellent; and is uſed particularly in inflammations of the eyes. Its preparations are,—*Lapis calaminaris præparatus*; Edin. and Lond.—*Tutia præparata*; Ed. and Lond.—*Calx zinci*, vulgò, *flores zinci*; Ed.—*Zincum calcinatum*; Lond.—*Vitriolum album*; Ed. made of zinc and ſulphuric acid.—*Zincum vitriolatum purificatum*; Lond.—*Aqua vitriolica*; Ed.—*Ceratum è lapide calaminari*; Ed.—*Unguentum è tutiâ*; Ed. and Lond.—*Unguentum è calce zinci*; Ed.

But certainly, it might be eaſy to ſubſtitute preparations of this metal, inſtead of ſome of theſe, which could be much more depended on. For lapis calaminaris is extremely different, (*Vide Eſſays on different kinds of it, by Margraaf,*) and may accidentally contain arſenic and other minerals.

With reſpect to tutia, ſee the experiments of Neuman, which ſhew it plainly to be artificial. And it is ſeldom ſufficiently levigated for ointments.

Both of theſe might be excellently ſuperſeded by a pure calx of zinc, or pompholix, which is extremely fine: And the vitriolum album by an artificial ſulphat of zinc.

When the chemical ſtate of the preparations is once ſuch as may be depended on, they are medicines of very uniform operation, and of conſiderable powers. The ſulphat in the doſe, a drachm or a drachm and a half, is a quick emetic, with little diſtreſs or ſickneſs. The calx in much ſmaller doſes, not exceeding five grains, produces ſickneſs and vomiting. We are but little informed as yet as to the internal uſe of the preparations of zinc. But it has been long known as a powerful aſtringent, emollient, and cooling application, when we deſire to remove the remains of a tedious inflammation, and reſtore ſtrength to the veſſels. The ſulphat and nitrate, in the quantity of two grains to an ounce of water, anſwer very well in ſuch caſes.

GENUS VII.—BISMUTH, OR TINGLASS.

Bismuth has a near reſemblance to antimony in external appearance. It is nearly as brittle, and exhibits the ſame texture when broken. But it is much heavier, its ſpecific gravity being 9,823; and the colour of it inclines a little to red. It is alſo more fuſible, and leſs volatile than antimony. It melts ſooner than lead; and flows the thinneſt of all the metals. It alſo expands in congealing, and therefore takes the fineſt impreſſions of its mould.

This metallic ſubſtance is eaſily calcined to a moderate degree, forming in its oxydated ſtate a very thin yellowiſh glaſs, one-eighth heavier than the metal. But it is difficult to calcine it further; at leaſt the oxyd of it is always fuſible in a moderate red heat; by which

quality, and ſome others, it reſembles the oxyds of lead. It may be got, either by keeping the biſmuth melted, and ſtirring it conſtantly, to expoſe the different parts of it to the air, or more quickly, by way of ſcorification in a more violent heat, which may calcine it faſter, and melt the calx as faſt as it is formed; ſo that it may conſtantly run off from the ſurface of the melted metal, and leave it expoſed. The metal ſmokes conſtantly, while any of it remains uncalcined; and a faint blue flame may be obſerved on its ſurface.

It is eaſily reduced again, by melting it with addition of charcoal, or of the black flux.

When we try it in mixture with ſalts, we find that the ſulphuric acid acts only when applied ſtrong, and aſſiſted with heat. The metal is then corroded and oxydated, by attracting oxygen from the acid; but we do not get a ſoluble compound.

A ſoluble compound of this metal is beſt and moſt eaſily obtained by the action of the nitric acid, which diſſolves it with a ſtrong effervescence, and the production of great heat, red vapours, and nitrous gas, in conſequence of the abſtraction of oxygen from a part of the acid by the diſſolving metal. The ſolution, when completed, is almoſt colourleſs; and the compound it contains is liable to ſuffer an imperfect ſeparation of the acid from the metal, when we dilute it largely with water.

This precipitate has been ſuppoſed by ſome authors to be the pearl white, ſaid to be employed as a coſmetic; and it is ſaid alſo that the tranſpiration by the ſkin blackens the oxyd, as if by an imperfect reduction, and thus deſtroys the ſkin. But I believe that this is a miſtake, having examined many ſpecimens of pearl white, which I found to be precipitates from a nitrate by a ſolution of common ſalt, or of tartar. Water alone makes but a very imperfect ſeparation, and leaves ſo much acid adhering to the metal, as unfits it for any ſuch purpoſe.

In conſequence of this mutability of colour by the ſteams of inflammable ſubſtances, the ſolutions of biſmuth, like thoſe of ſome other

metals, form what are called *ſympathetic inks;* that is, inks which are inviſible, till ſomething has been done to the paper. When we write with the ſolution of the nitrate of biſmuth, the exhalation from hepar ſulphuris, or putreſcent animal ſubſtances, ſoon make the writing legible. All bad ſmells have this effect.

You will find in Neuman *(p.* 107, 108.) a number of experiments upon the precipitation of biſmuth from aquafortis, by a variety of different additions, which you may conſult, if you have occaſion to attend to this particular ſubject.

The ſame author alſo deſcribes a proceſs for combining biſmuth with the muriatic acid, by means of muriat of mercury, and the conſequences of diſſolving it with vegetable acids and alkalis, and of uniting it with ſulphur, with which it forms a maſs very like crude antimony. To him, therefore, I refer you for theſe particulars, which are not ſo important as to require our time. Mr. Pott of Berlin alſo may be conſulted, who wrote a diſſertation upon this metal.

The compounds of biſmuth are remarkably fuſible, ſo that it may be employed in the compoſition of ſolders for lead or tin. The fuſible metal, called *Newton's metal*, has biſmuth for its principal ingredient. The beſt proportion for the fuſible metal are, eight parts of biſmuth, five of lead, and three of tin. When thus mixed, it will become fluid in a temperature ſomething below that of boiling water. It is from the ſame cauſe, probably, that when diſſolved in mercury, it diſpoſes the mercury to form more fluid amalgams with other metals, particularly with lead, than ordinary. And hence it has been propoſed to be added to mercury, the more readily to diſſolve lead balls lodged deep in a wound. Mr. Lewis ſays *(Notes on Neuman, p.* 93.*)* that mercury united into a fluid amalgam with one-fourth, one-eighth, or one-twelfth of its weight of biſmuth, diſſolves maſſes of lead in a gentle warmth, without the neceſſity of agitation. Whether this would anſwer the purpoſe, I cannot poſitively ſay, becauſe the biſmuth, or part of it, ſeparates in the form of powder while the lead diſſolves, which

might poſſibly prove inconvenient. An abuſe of this quality of biſmuth has been practiſed in adulterating mercury.

The principal uſes of biſmuth are, to mix with tin for proper hardneſs in the compoſition of pewter for ſolders for lead and tin. It is ſometimes uſed alſo in the compoſition of metal for printers types; and when uſed, ſeems to be intended for greater tenuity of fuſion, and ſharp impreſſion. The proper degree of hardneſs is always procured by the cheaper regulus of antimony. With lead one part, tin one, biſmuth two, and mercury ten parts, it compoſes a kind of fluid amalgam, which being moved backwards and forwards in a clean glaſs veſſel, leaves a train behind it, adheres to the glaſs, and foils or ſilvers it. It is therefore uſed for foiling the inſide of glaſs globes. (*Vide Boyle's Treatiſe on the Uſefulneſs of Exper. Phil.; and for other uſes, vide Neuman, p.* 112.) But it has never been introduced into the materia medica, nor is there any reaſon yet for introducing it.

Its ore is moſt plentiful in Saxony, near Schneeberg. There is ſome too in Bohemia, and in Dauphiné, and ſome in England. Sometimes the biſmuth is found pure; ſeldom or never a vein of it pure, but intermixed with other ores, eſpecially arſenical, and particularly the ore called *cobalt*. The biſmuth is eaſily ſeparated from the ore by eliquation. It ſeparates in its metallic form, and runs along the inclined hearth into a channel, by which it is conveyed to a receptacle, where it is defended from the further action of heat. Mr. Macquer gives a long account of a very curious tincture, or ſolution, obtained from ores of this kind; but as the biſmuth has no part in its production, I ſhall conſider it afterwards in its proper place.

GENUS VIII.—COBALT.

This name has been long appropriated to certain minerals or ores, which, when duly prepared, and melted with glaſs or enamels, give them a deep and rich blue colour. In their natural ſtate, theſe ores

have commonly the metallic opacity and luſtre, and a colour reſembling that of iron, although it is various in conſequence of their being more or leſs compounded with other minerals.

Thoſe parts of them which are long expoſed to the air are liable to decay, and contract a ſort of ruſt, which has a pale purpliſh red or pink colour, like that of peach bloſſoms. It is named *cobalt bloom.*

All the varieties of cobalt generally contain a large quantity of arſenic, the greater part of which is eaſily ſeparated from them by uſtulation: After which, the remaining metallic matter is an oxyd of a dark colour like ſoot, or ſometimes it has a violet hue. It ſtill retains arſenic, which appears to have been changed by the uſtulating proceſs into its acid ſtate, and in that ſtate remains ſtrongly combined with the oxyd of cobalt.

The dark coloured oxyd, obtained by uſtulating the ores of cobalt, is named *zaffre* *; and when added to glaſs, or the materials for making glaſs, it gives it the blue, or deep violet colour, in proportion to the quantity uſed. But it was employed for this purpoſe a long time before we knew that it could be reduced to a metallic ſtate. Dr. Brandt, of the Swediſh academy, firſt ſhewed that it may be procured by the help of the common inflammable fluxes, and he called it *regulus of cobalt.* From the experiments he made upon it, as well as the properties of its calx which were known before, there is no doubt but that it is a metallic ſubſtance,—a ſemi-metal of a peculiar kind. The following are its moſt remarkable qualities.

Its colour approaches to that of iron or antimony. It breaks with a granulated ſurface, like ſteel. Its ſpecific gravity is 7,7. It requires a pretty ſtrong red heat to its fuſion, and can be calcined without difficulty; but its calcination goes on ſlowly, like that of copper, and without the appearances of inflammation. The calx produced from

* This zaffre, however, which we get in the ſhops, contains but a fourth or fifth part of this oxyd, and the reſt is powdered flint.

it is always of a blackiſh colour, and is not eaſily melted by itſelf. But if it be added to glaſs, it melts with it, and colours it to different ſhades of blue,—from the lighteſt to a deep blue, which appears black.

Of the acids, aquafortis diſſolves it the moſt readily, and with effervescence. The ſulphuric acid will not act upon it, except when applied ſtrong, and with the aſſiſtance of heat. A very diluted acid, however, will readily diſſolve the oxyd obtained by precipitation from any acid, by alkali or lime. The muriatic acid acts beſt upon the calx, or when it is aſſiſted with a little of the nitric acid. The ſolution has a faint roſe colour, which becomes green when heated.

All the ſaline compounds thus produced are ſoluble in water, and capable of being largely diluted without ſeparation of the acid; and the ſolutions are all of a roſe colour, or reddiſh.

The muriatic ſolution, as alſo the ſaline compound which it contains, is remarkable for changing its colour when gently heated, and reſuming its former colour when the heat leaves it. Air deprived of its natural humidity by quicklime, or by ſulphuric acid, produces the ſame effect; and breathing damp on it effaces the green, though hot.

This ſolution is the *ſympathetic ink* of Mr. Hellot, and is the moſt curious of all the preparations which go by that name. The proceſs for it is deſcribed by Macquer. Hellot deſcribed it as produced from ore of biſmuth; but this was a miſtake, as I mentioned when deſcribing the properties of that metal. The calx, or zaffre, is diſſolved in aqua regia, (which keeps it much better ſuſpended than aquafortis) and the ſolution, when cold, has a pale roſe colour, and becomes green when hot. Writings with this ſolution are inviſible (when recently done) in the cold; but when held before a fire, they acquire a beautiful leek green colour; this diſappears again when cold, and may be renewed by heat; and this may be repeated as often as we pleaſe, taking care that we do not make the paper too hot. This will render the colour permanent. Frequent repetition has ſomewhat of this effect; and in this reſpect, a ſolution of the calx in muriatic acid is preferable

to that in aqua regia. If a drawing of a plant of abundant foliage be waſhed with a full ſtraw colour, which is not very unlike the withered leaf of ſome plants, the ſolution of cobalt being laid over it, raiſes it to a very beautiful lively green, and is a pretty fancy for a fire-ſcreen. There is another preparation of a ſimilar kind, made by boiling oxyd of cobalt in ſixteen times its weight of diſtilled vinegar, till the liquor is reduced to one-fourth;—it is filtered, and again reduced by evaporation to one-half;—muriat of ſoda is now added to it,—and the muriatic acid takes the oxyd from the acetous. This ſolution is inviſible, like the other, when cold, but when heated, ſhews a fine blue, which diſappears on cooling *.

In trying to mix cobalt with other metals, it has been found incapable of uniting with mercury and lead, except in ſmall quantity, or with ſilver, according to Bergmann. It mingles with all the reſt, and makes the moſt malleable metals quite brittle; but it was thought rather to increaſe the toughneſs of iron.

It is precipitated from acids by zinc, but not by iron.

When borax, which has been tinged with cobalt, is boiled in water, the water diſſolves the borax, and leaves a firm gelatinous matter, which becomes friable by drying, and of a tranſparent roſe colour, like cobalt bloom.

The only uſe that I know to be made of cobalt, is to tinge glaſs and enamels. The calx or zaffre, being mixed with a certain proportion of flint or glaſs, is melted, and forms a glaſs of a rich purpliſh blue.

* The action of the neutral ſalts has not been much attended to. It is ſomewhat remarkable that it ſcarcely detonates with nitre,—leſs than even copper. Yet in its oxydation, it ſeems to combine with more oxygen than any other metal. The oxyd produced from 100 grains weighs 140. (Fourcroy.) Nitre calcines or oxydates it. What becomes of the caloric of the oxygen? The difficulty to reconcile this with the general doctrine is great, but not peculiar to this metal; for the deflagration of the metals with nitre is by no means in the proportion that we ſhould expect from their increaſe of weight by calcination.

EDITOR.

This is ground to a coarſe powder, and ſold by the name of *ſmalt*,—in which ſtate it is uſed by the ſign-painters. Smalt is ground in mills to a very fine powder, which is ſorted, by its precipitation in water, into parcels of different fineneſs, and ſold by the name of *powder blue*. The ſame compound, ground to the utmoſt degree of fineneſs, is uſed in painting all the blue that we ſee on porcelain, Delft ware, and all other imitations of porcelain. Some of it has a richneſs of colour ſurpaſſing all other works of the pencil. This is particularly remarkable in the Saxon porcelain. The painters in enamel complain that it is ſo fuſible, that the heat neceſſary for raiſing their other colours makes the blue ſpread juſt as ink does on bibulous paper.

GENUS IX.—NICCOLUM.

The name now given to this metal is derived from the name which was firſt given to the ore of it by the German miners, at Freyberg in Saxony, where it is moſt abundant.

As the colour of this ore reſembles in ſome degree the colour of copper, they expected at firſt to get copper from it; but not ſucceeding in their attempts to get copper from it by any proceſs, they gave it the name of *cupfer nickel*,—the literal tranſlation of which into Engliſh is *Niccol's copper*.

A laborious inveſtigation of the component parts of this ore by ſeveral of the modern chemiſts, eſpecially Cronſtedt and Bergmann, has ſhewn that it contains a peculiar metal, to which the name *niccolum* is now appropriated, but which is intimately and ſtrongly combined in the ore with ſeveral others, and with ſulphur. Cronſtedt was the firſt who made the diſcovery. The other metals preſent in this ore are iron, arſenic, and generally ſome cobalt. And all theſe ingredients cohere ſo ſtrongly together, that an attempt to ſeparate them, or to obtain the niccolum pure, is a taſk of the greateſt difficulty and labour. Of this you will be ſatisfied, when you look into Berg-

mann's diſſertation or eſſay on niccolum, in the ſecond volume of his Chemical Eſſays. He was at aſtoniſhing pains with it; and after all, was not ſatisfied that he had completely ſucceeded. The moſt highly refined niccolum that he was able to obtain by his great labour and ſkill was ſtill attracted by the magnet, and had a very conſiderable degree of toughneſs or malleability. And he remained doubtful whether theſe qualities proceeded from iron ſtill adhering to it, or are qualities belonging to this metal as well as to iron.

Nickel reſembles biſmuth in its colour,—it being white, with a caſt of reddiſhneſs; and its ſpecific gravity is about 8,66.

When it is expoſed to the action of the air and heat for calcination, it is ſlowly calcined or oxydated in the ſame manner as copper *, but the oxyds got from it are of a green or greeniſh colour, whereas the oxyd of copper is ſooty black.

It can be diſſolved by moſt of the acids; and its ſolutions are all of a pleaſant green colour. In theſe the metals is ſtrongly combined with the acid; and no other metal has the power to precipitate it.

It can only be precipitated by the fixed alkalis, and the alkaline earths, and by ſome of the compound ſalts or ſaline compounds which contain ſome of the acids, for which this metal has a ſtrong attraction, and which form with it inſoluble compounds. The metal is combined with ſuch acid in this caſe, in conſequence of a double elective attraction, and precipitates with it.

When it is precipitated by alkalis, it is neceſſarily in an oxydated ſtate; and in this ſtate can be rediſſolved by adding more of the alkali. The volatile alkali eſpecially diſſolves it with facility, and can even act on the pure metal in its metallic form, and always forms with it a blue ſolution.

In trying to mix the oxyd of nickel with vitrified earthy ſubſtances, we find that it can be employed to give a colour to glaſs; and the colour it gives is a reddiſh yellow. No other property of it relative to the earthy ſubſtances has yet been diſcovered.

* Cronſtedt ſays that when ſtrongly heated it emits ſparks, or brandiſhes, like iron.

Of the inflammables, ſulphur readily unites with it, and adheres to it very ſtrongly. It alſo diſpoſes the nickel and arſenic to be more eaſily ſeparated by uſtulation. And a part of Bergmann's experiments for refining niccolum was founded on this fact.

Phoſphorus alſo combines with nickel; and they adhere ſtrongly, ſo as to bear a melting heat. Long expoſure to this heat and the action of air diſſipates the phoſphorus, the metal all the while having a ſenſible fluttering glow. When it cools, ſo as to freeze, the phoſphorus flames out very briſkly. This is probably owing to the emerſion of latent heat.

Nickel can be mixed with moſt of the other metals, excepting quickſilver, and a few others to be mentioned afterwards. And it is ſaid that the Chineſe *packfong*, which is a white metal, or metallic mixture very like ſilver, is compounded of copper combined with nickel and zinc. We ſhall take farther notice of this when treating of copper.

GENUS X.—LEAD.

LEAD is the ſofteſt of the metals; and has ſcarcely any elaſticity or ſound. It is the leaſt ductile; and cannot be beat into thin leaf. Its coheſion is weak. A wire one-tenth of an inch in thickneſs breaks with 29¼ pounds; but what is very remarkable, a rod of caſt lead becomes almoſt four times as ſtrong by wire drawing.

Its ſpecific gravity is 11,35.

The fuſibility of lead is familiarly known to you all. When paſſing from a fluid to a ſolid ſtate, it has a ſingular intermediate ſtate, in which it can be eaſily divided into very ſmall parts or grains *. When poured then into a hot iron mortar, ſet ſo as to cool very ſlow-

* This obtains, in a greater or leſs degree, in all bodies, while they congeal. It does not ſurpriſe us in the brittle metals, nor in the roaching of alum, and many other caſes, where the ſolid is brittle, and the fluidity thin; but in viſcid fluids, or even in metals with a clammy or oily appearance, it attracts more attention, and it is even thought peculiar to them. EDITOR.

ly, if it be continually ſtirred with a ſtick, it comes to a ſtate in which the parts cohere ſomewhat like wet or greaſy ſand; and by ſtirring it now briſkly, the greateſt part can be reduced to the ſize of a coarſe ſand. This is called the granulation of a metal. An apparatus is made on purpoſe for this operation;—a ſort of oval wooden box, the inſide of which has partial partitions, and is rubbed all over with chalk. The melted lead is poured into this box, the lid fixed on, and the box is violently ſhaken for ſome time. This daſhes the lead againſt the ſides and partitions, and ſoon breaks a great deal into grains: But the other method will convert more of it into grains, becauſe it does not cool ſo faſt.

There is another, and more curious manufacture of lead, in which it is alſo divided, when fluid, into very ſmall parts. This is the manufacture of ſmall ſhot. A little orpiment or arſenic is added to the lead, which diſpoſes it to run into ſpherical drops, much more rapidly than it would do when pure. The melted lead is poured into a cylinder whoſe circumference is pierced with holes. The lead, ſtreaming through the holes, ſoon divides into drops, which fall into water, where they congeal. They are far from being all ſpherical, however, many being ſhaped like pears; and muſt be picked. This is done by a very ingenious contrivance. The whole is ſifted on the upper end of a long ſmooth inclined plane, and the grains roll down to the lower end. But the pear-like ſhape of the bad grains makes them roll down irregularly, and they waddle, as it were, to a ſide; while the round ones run ſtraight down. They are received into a ſort of funnel which extends from the one ſide of the inclined plane to the other, and is divided by ſeveral partitions, ſo that it is really the common mouth of ſeveral funnels, which lead to different boxes. Thoſe in the middle receive the round grains. On each ſide are grains of a worſe ſhape, but good enough for low-priced ſhot: The grains which have gone far aſide are melted again. The good ones are ſorted into ſizes by ſieves. *(See Note* 28. *at the end of the Volume.)*

Lead is caſt into ſheets, by letting it run out of a box through a long horizontal ſlit at the bottom, while the box is drawn along the table, leaving the melted lead behind it to congeal. The Chineſe caſt it extremely thin in this way on cloth, for lining their cheſts of tea.

Lead is very calcinable. It calcines ſlowly in a heat a little above its melting one. Its ſurface is quickly covered with a dirty wrinkled pellicle, which is renewed as faſt as it can be raked off. This calcination goes on moſt quickly at a heat rather below redneſs. If allowed to get too hot, the ſurface of the pellicle calcines in a moment to a much greater degree, forming a fluid film, which protects the reſt from the action of the air.

Lead calcines much more quickly and perfectly by way of ſcorification. Great quantities are changed into calx by this method in the proceſs for ſeparating it from ſilver, which is generally found in lead ores. This is done in a reverberatory furnace, the bottom of which, called the hearth, is made of materials which can withſtand the diſſolving power of this calx. The lead is pretty ſtrongly heated; and the fluid calx immediately forms on its ſurface. Two pairs of bellows blow ſlantingly on the middle of the melted lead, and thus blow this ſcum over to the other ſide of the hearth, where there is a channel by which it may run off. It collects in a maſs of an unequal flaking texture, juſt as we ſhould expect from the way by which it is forced to accumulate. By thus blowing off the ſcum, the air is continually applied to metallic lead, which is in a fit condition for abſorbing its oxygen. But it is very imperfectly calcined, becauſe by running off the hearth, the air no longer acts on it. It is of a greeniſh yellowiſh colour, with here and there ſome ruddy ſtreaks, where it has been more oxydated. The calx, in this ſtate of oxydation, has ſome volatility, and very noxious vapours riſe from it during this operation, which produce terrible effects on the human body,—bringing on, ſometimes in a moment, an univerſal paralyſis and rigidity, ſo that the arm that was lifted up cannot be let down again.

The calx thus formed, when allowed to cool, congeals, as I juſt now obſerved, into a maſs which is not tranſparent, but of a yellow colour, and plated texture, and is called *litharge*. The litharge in the apothecaries' ſhops is the ſame matter, broken into a coarſe powder.

The lead gains about one-tenth of its weight by oxydation. This was the phenomenon which induced the French chemiſt Rey, in the 17th century, to aſcribe the calcination of metals to the combination of them with air; a truth which no body attended to for more than a century. This obſervation was much more diſtinct than Dr. Mayhow's, to the ſame effect, on diaphoretic antimony.

This is not however the moſt highly calcined calx of lead. Litharge can be calcined more perfectly, by beating it to powder, and expoſing it two or three days to a heat hardly ſufficient for producing the moſt obſcure degree of ignition. This is done alſo in a low reverberatory furnace; and the flame of wood ruſhing along it is beat down by the form of the arch, ſo as to play continually on the ſurface of the litharge. The colour of it is thus gradually changed from the yellow to an orange, and from that to a bright red, when it is called *red lead*, or *minium*.

We have here a ſtriking example of the ſuperior power of a moderate heat to that of a ſtronger one for enabling a metal to attract plenty of oxygen, and become thereby highly calcined; for this very minium, if expoſed to a full red heat, gives out a quantity of vital air, returning at the ſame time to a leſs calcined ſtate, and becoming a yellow powder, which, if the heat be increaſed, melts into litharge.

A quantity of vital air can be expelled from minium alſo, by the elective attraction of the ſulphuric acid, aſſiſted by a gentle heat. By this eaſily ſeparable portion of vital air which minium contains, it has the power to oxygenate to a certain degree the muriatic acid, as Scheele has obſerved.

All the calces of lead are eaſily fuſible, forming a thin fluid without viſcidity; and when pure, concrete like litharge. All theſe oxyds,

by melting them with one-eighth of charcoal, are eaſily reduced. Common red wafers burn and yield drops of lead. Red lead on a bit of charcoal is converted into lead in a moment by the blow-pipe. Dr. Prieſtley reduced it in ammonical gas; and water was produced at the ſame time. He alſo reduced it in hydrogen gas, and alſo had water. By giving its oxygen ſo readily to other ſubſtances, this oxyd greatly promotes the calcination of other metals. Red lead, melted with iron filings, will be reduced, and the iron oxydated or corroded.

In the manufactures of lead work, they prevent the calcination by throwing greaſe or pitch upon the ſurface,—the operation of which is eaſily underſtood. When a private perſon has occaſion to employ a plumber, he may obſerve that they never throw greaſe upon the melting pot, becauſe the droſs, as they call it, is conſidered as uſeleſs by the employer, and becomes the property of the workman. He rather encourages its formation, and contents himſelf with clearing the ſurface with a piece of deal before he caſts the lead *.

The older chemical writers ſpeak of a golden and a ſilver litharge: Theſe names are given to litharge, as it is more of an orange or of a grey colour. The firſt is moſt abundant when the flame of wood is employed, and the other, when other fuels are uſed. Theſe diſtinctions are now neglected, there being but one calx, which when it cools greatly is of a glaſſy ſtructure, with traces of oblong cryſtallizations.

Such is the nature of lead with regard to heat. In trying it with the different acids, we find that this metal is affected by them nearly in the ſame manner as ſeveral of thoſe we have already deſcribed.

The ſulphuric acid will hardly act upon it, except the lead be in thin plates, and the acid applied ſtrong, and with the aſſiſtance of heat. During its action, part of the acid becomes volatile and ſulphurous, its oxygen being taken by the lead. And when the operation is

* This obſervation is by Dr. Hooke, who ſaid, in a meeting of the Royal Society, that the plumber can make it all droſs, and much more, by the air with which it combines, *(Birche's Hiſt.)* EDITOR.

managed in a particular manner, part is changed into perfect ſulphur. The oxydated lead forms with the reſt of the acid an inſoluble ſulphat of lead. Leaden veſſels are uſeful in preparing vitriol and alum, and even ſulphuric acid itſelf, in conſequence of the inſolubility of the ſulphat of lead.

The nitric acid, properly diluted, diſſolves lead the moſt eaſily, producing ſome nitrous air. It forms a ſoluble compound, which bears to be largely diluted with water without being decompounded; and it gives cryſtals which decrepitate with great noiſe, but do not deflagrate.

The cryſtals of this ſalt are of a ſingular ſhape, namely *triangular priſms*, like thoſe uſed inoptical experiments. I know no other cryſtals of this form. They have not a fine edge, but a narrow facet ſcarcely viſible. Theſe are frequently ſo grouped as to form hexagonal priſms, whoſe ſides are ſtriped or fluted, by the want of every ſecond triangular priſm, which is the primitive molecula, or nucleus, of this cryſtallization.

This nitrate has its ingredients but weakly united: A moderate heat long continued will expel the acid from it,—leaving a fuſible oxyd in the retort.

The muriatic acid, in its ordinary ſtate, acts but very ſlowly and imperfectly on this metal. Woulfe ſays that ſome inflammable air is produced during the ſolution: I have never found this. It acts much more powerfully in the form of the corroſive muriat of quickſilver,—the lead being then ſupplied by the quickſilver, with both oxygen and acid at the ſame time. Or if the lead has been previouſly oxydated in any other way, the muriatic acid very readily joins with it: Nay, it will ſometimes be oxygenated by a calx of lead. Such a calx may then be conſidered as ſuper-oxygenated. When, for example, we add muriatic acid to the nitrate of lead, we immediately form a muriat of lead, which is always leſs ſoluble than the nitrate.

The ſame thing happens if we add to the nitrate of lead any neutral ſalt which contains the muriatic acid. A double exchange takes place.

The qualities of the muriat of lead are, difficult ſolubility in water, and volatility. It is remarkably fuſible, melting before it is red hot. When cold, it congeals into a ſemi-tranſparent uniform maſs, called *plumbum corneum*, on account of its reſemblance to a muriat of ſilver, which has long been called *luna cornea*, from its colour, flexibility, and a degree of ſoftneſs, which allows it to be cut with a knife like horn. Plumbum corneum is the moſt powerful aſtringent that I know.

It is alſo conſiderably volatile, like all the metallic muriats; but has little of the butyraceous appearance which moſt of them have.

The acetous acid can alſo be combined with this metal, ſo as to reduce it to a ſaline and ſoluble form; but it unites much more readily with ſome of its oxyds than with the metal in its perfect ſtate.

The oxyd which diſſolves the moſt readily, is a carbonat of this metal, well known by the name of *white lead*, or *ceruſſa*, formed by a proceſs contrived on purpoſe.

Vinegar is put into a ſtone-ware pot, and at the diſtance of two inches from its ſurface, there is a croſs of wooden bars, on which is ſet a roll of ſheet lead, of ſix feet long, and ſix inches broad, and about one-tenth thick. It is rolled up looſe, with the diſtance of about one-fourth of an inch between each turn. The pot is ſet in a bed of tan, or horſe dung, and covered with a plate of lead. In about three weeks, the whole ſurface of the ſheet is covered with a ſaline cruſt, which is detached by unrolling the lead, and ſcrubbing with a wire bruſh. The ſheet is then rolled up again, and undergoes the ſame proceſs till the whole is diſſolved *.

* This proceſs merits the attention of the philoſophical chemiſt. Dr. Black calls white lead, not a ſimple oxyd of lead, but a carbonat; and in fact, white lead contains a very great quantity of carbonic acid, and this acid ſeems to be combined with the lead. The inſolubility in water does not prove that white lead is not a combination of the metal with an acid, for we know others, ſuch as the ſulphat of this metal, not more ſoluble. How does the lead acquire this acid, and what is the nature of the vapour, after it has furniſhed this ingredient? EDITOR.

Here the acid is found to have greater effect when applied in the form of vapour. A certain quantity unites with the lead, in the form of a white powder, which is afterwards much more eaſily diſſolved. This ſubſtance, diſſolved in diſtilled vinegar, affords ſalt of lead, called *ſaccharum ſaturni*, from the ſweetiſh taſte with which it affects the tongue, reſembling that of ſugar. It cryſtallizes, or rather grains, very readily. If the ſalt be again diſſolved in more vinegar, it combines with a greater proportion of it, becomes more ſoluble, and affords fine cryſtals.

With the tartarous acid, lead forms a compound very inſoluble. It may be produced by boiling a ſolution of tartar, and adding any pure oxyd of lead. The ſuperfluous acid of the tartar joins with the lead, as with chalk, and forms an inſoluble ſediment; and the tartar is thus neutralized, being deprived of the acidulating part of its acid.

Or if, inſtead of an oxyd of lead, we take a compound of this metal with nitric or acetous acid, and add this compound to a ſolution of tartar, or any liquor which contains tartar diſſolved in it, the tartar is then completely decompounded by a double elective attraction; the whole of its acid uniting with the lead, to form a white inſoluble precipitate.

Lead alſo forms an inſoluble compound, in the ſame manner, with the acid of phoſphorus, which can therefore be precipitated from urine by a ſolution of lead.

When we, in the next place, compare the forces of attraction between lead and theſe different acids, we find the ſtrongeſt is that of the ſulphuric acid. Other metals in general unite moſt ſtrongly with muriatic acid; but in the caſe of lead, it is the ſulphuric acid that is moſt ſtrongly attracted, and when combined with the lead, it always forms an inſoluble compound. It therefore precipitates lead from other acids, by joining itſelf to this metal in their place. This happens, not only with pure ſulphuric acid, but with any ſalt or ſaline compound which contains the ſulphuric acid. In however ſmall

quantity the ſulphuric acid be thus applied to the diſſolved lead, we have a double exchange, and a proportional part of the lead precipitates with it.

The ſolutions of lead, eſpecially the acetite, are therefore, when properly uſed, an exceeding nice trial of the preſence of the ſulphuric acid, pure or compounded, in mineral waters, or other mixtures, by occaſioning turbidneſs.

After the ſulphuric acid, the muriatic is next in force of attraction for lead. As I already remarked, it ſeparates the nitric acid, and joins itſelf to the lead in its place, forming the plumbum corneum, or muriat of lead.

The muriat of ſoda, and the muriat of lime or magneſia are decompoſed by the oxyd of lead: Hence the corroſion of leaden pipes. A proceſs has been followed for procuring the foſſil alkali by employing litharge. Accordingly, the decompoſition of the ſea ſalt is accompliſhed, and ſoda is produced. But the expence would be far too great, were it not that the muriat of lead is manufactured into a fine yellow pigment of conſiderable demand. The manufacture is chiefly carried on for the pigment, and the ſoda is a very ſecondary object.

Lead has alſo a ſtrong attraction for the tartarous acid, and the phoſphoric acid, and will quit other acids to unite with them; and they always form with it inſoluble compounds. They therefore precipitate the lead from its ſolutions in the nitric or acetous acid, and the lead precipitates them. I made a number of experiments on ſuch precipitations of lead ſome years ago, in conſequence of which I found it eaſy to diſtinguiſh different kinds of vinegar from one another.

Theſe compounds of the different acids with lead are all decompounded by common mild fixed alkalis, or carbonats of alkalis, and by calcareous earth *. Some of the other metals alſo attract acids

* *Quæritur.*—Is the precipitate of lead, produced by a mild alkali, the ſame with white lead? It is ſurely a carbonat, and white lead is not a pure oxyd.

EDITOR.

more ſtrongly, as zinc, which ſeparates it in fine metallic cryſtals. There are alſo two of them that can be decompounded by heat alone, viz. the nitrate and the acetite of lead; the firſt, juſt in the ſame manner as the nitrate of quickſilver, with this difference, however, that the oxyd of lead is not reduced. The ſecond may be decompounded with a heat inferior to red, and is ſometimes decompounded by ſuch a heat, in order to extract the vinegar from it in a very ſtrong ſtate. During this operation the lead calx is reduced,—a ſmall quantity of inflammable fluid, reſembling alcohol, is produced, and found mixed with the vinegar.

From Lemery's account of this diſtillation, it does not appear that much pure or ſtrong acid is obtained. He rectifies the diſtilled liquor afterwards by itſelf, to ſeparate the more volatile half of it, which is inflammable, like ſpirit of wine. The other half, he ſays, is called *oil of Saturn*, and is uſed as a detergent for the eyes of horſes.

But by means of the ſulphuric acid, an exceeding ſtrong vinegar can be got from ſaccharum ſaturni. The ſaccharum being firſt diſtilled by itſelf, with a moderate heat, gives an ardent ſpirit; after which, ſulphuric acid being added, extricates a ſtrong vinegar.

Sulphat and muriat of lead cannot be decompounded by heat. The firſt melts in the fire, without ſeparation of the acid, unleſs inflammable matter be made to touch it, which volatilizes the acid. The muriat not only melts, and that very eaſily, but alſo proves volatile, and will wholly evaporate without being decompounded, and cannot be reduced by inflammable matter alone.

Alkalis, in their liquid form, eſpecially if cauſtic, corrode lead.

Nitre calcines it, when applied with a proper degree of heat, and converts it into a yellow powdery ſubſtance, preciſely ſimilar to litharge in all its properties.

Common ſalt is decompoſed by calx of lead.

Sal ammoniac, diſtilled with granulated lead, is partly decompounded by the lead, but much more eaſily by the calces of lead; and this

is the readieſt way for plumbum corneum. The volatile alkali is cauſtic, or nearly ſo.

The muriat of lead made with ſal ammoniac, when heated with a covered patella under the muffle, becomes paſty, and in ſome degree fluid, diminiſhing much in bulk. When it is juſt red hot, it begins to fume, and upon increaſing the heat ſtill more, it becomes perfectly fluid, contracting ſtill more in its bulk. It now emits elaſtic fumes. When allowed to cool, it is of a greeniſh gray colour, with a little tranſparency, and is quite brittle. When viewed with a microſcope, its grayneſs appears owing to very ſmall globules of reduced lead.

With reſpect to the earths, when they are expoſed to melting heats with the calces of lead, we have an opportunity here to obſerve one of the moſt remarkable and uſeful qualities of the metal. This is a power which its calces have to diſſolve and melt in the fire the earthy ſubſtances, very few of which can reſiſt this power; and they form with them glaſſy compounds. This property is ſo eminent in the calces of lead, that no earthen veſſels can be contrived to contain them melting for any length of time. Some chemiſts have ſaid that they are poſſeſſed of ſuch a ſecret, but do not chooſe to diſcover it. Pott of Berlin has made a vaſt number of experiments, in order to diſcover a compoſition of earthen veſſels which can reſiſt the action of the glaſs of lead. The reſult of his reſearch is, that pure clay, which is free from iron, is the beſt. And as it muſt be kneaded with ſome dividing matter like ſand, to prevent its cracking by ſudden changes of temperature, the beſt addition is pure clay, which has already been burnt in the moſt intenſe fire. This, beaten to powder, and ſorted into a ſand ſomewhat coarſe, makes a compound which will reſiſt fuſion by the calx of lead much longer than any other: But it alſo will imbibe it, and then will melt, as ſalt diſſolves in water.

In conſequence of this property, lead is employed in many proceſſes, in which it is neceſſary to bring earthy ſubſtances into fuſion, as in working the ores of the precious metals. Alſo, on account of

its being tranſparent, it is employed in making the fineſt kinds of glaſs, called *flint-glaſs* and *paſtes*. This name is given to the artificial glaſſes for imitating the gems. The calx of lead is eminently fitted for this purpoſe, becauſe it communicates to the compoſition a greater refracting and diſperſing power than any ſubſtance except the diamond, and to this it approaches very nearly. Unfortunately, theſe paſtes are ſo very ſoft, that they ſoon loſe their brilliancy, being ſcratched by almoſt every thing. This great diſperſive power has enabled us to remove the defect of optical inſtruments by refraction, which had been long deſpaired of. Mr. Dollond, and Mr. Hall, a country gentleman, at the ſame time, and unknown to each other, diſcovered a method of conſtructing *achromatic teleſcopes*, by joining lenſes of crown and of flint glaſs. There remains, however, a great obſtacle to their perfection, which the ſuperior ſkill of the chemiſt only can remove. Flint glaſs is never uniform in its compoſition. The great weight of the calx of lead ſeems to make it fall down towards the bottom of the pot, and when the workman takes it up, and collects it into a maſs at the end of his pipe, by turning it round and round, it is collected in ſtrata of different denſity and refracting power, which greatly diſturbs the formation of a fine image in the optical inſtrument. A premium of ſeveral thouſand pounds is offered for the removal of this defect. It is remarkable that the calces of lead not only increaſe the refractive and diſperſive powers of the glaſſes of which they are ingredients, but that they produce the ſame effect in their watery ſolutions. Sir Iſaac Newton firſt obſerved that a ſolution of ſugar of lead had a much greater refracting power than pure water. Mr. Zeiher, an ingenious chemiſt of Berlin, by increaſing the doſe of minium, compoſed a paſte which ſcarcely yielded to the diamond in brilliancy and refracting power, and exceeded it in the diſperſive quality, by which the different colours of light are ſeparated from each other*. Minium,

* As the difference of diſperſive power in different ſubſtances is very conſiderable, and as it is much more remarkable with regard to ſome colours of light than others, it

with a very ſmall proportion of diaphoretic antimony, when mixed with flint, produces a paſte ſcarcely diſtinguiſhable from the fineſt topaz.

Calx of lead, or glaſs containing lead, is neceſſary for making all white opaque compoſitions called *enamels*. Arſenic and tin alone will not do.

Flint-glaſs and paſtes often have *veins*, or *eels*, as they are called, which differ in their refracting and diſperſing power from the reſt, like a mixture of ſyrup and water; and on account of this, are not uſed for mirrors. If the calx of lead be very redundant in ſuch glaſs, and eſpecially if it be not much calcined, it is of a yellow colour. It forms the glazing of common earthen ware, but it is very liable to corroſion by acids, which renders it very unfit for many culinary purpoſes. The ſolution alſo is very hurtful to the conſtitution. The common ſoft glazing on earthen ware is quickly corroded by vinegar, and ſuch ware cannot be uſed for holding pickles. There are no veſſels fit for this purpoſe but thoſe of the porcelain kind, or what we call ſtone-ware. Till within theſe 30 years it was made in great abundance in this country, and it had no glaze, but a ſlight ſuperficial vitrification of the ware itſelf, by the vapour of ſoda thrown into the fire-place while the whole kiln was in a white heat. The preſent ware for the table, which has ſupplanted the ſtone-ware, is a bibulous clay, glazed with lead; and pots for pickles and ſweet-meats are made of it. But they ſhould be rejected entirely for ſuch uſes, and we ſhould only uſe the ſtone-ware. It is ſtill to be had, but of a brown, or dirty colour.

Lead is eaſily recovered from glaſs which contains it. Such glaſs is liable to be ſmoked or blackened with the flame of the blow-pipe. This is nothing but the reduction of the lead.

has all the appearance of being owing to elective attractions for the rays of light. It is not improbable, therefore, that there may be found a ſubſtance that attracts them all alike. Such a ſubſtance would be a moſt precious diſcovery to the optician. In the mean time, it affords another ſtrong argument for the materiality of light.

EDITOR.

Of the inflammable ſubſtances, ſeveral act upon lead.

Many of the oils can diſſolve lead or its calces; and it is remarkable that they are diſſolved moſt readily, and in greater quantity, by the mildeſt, or the unctuous oils. The ſolution of the calces of lead in theſe requires the heat of boiling water to aſſiſt it; and when they have diſſolved a proper quantity, and are then allowed to cool, they form a maſs that is firm and hard when cold, but which becomes ſoft, and tough, and adheſive, by being warmed a little. On account of theſe qualities, and its oily nature, in conſequence of which it cannot be diſſolved or changed by humidity, it is very valuable.

The *emplaſtrum lythargyri*, or *commune*, of the ſhops, is made in this manner, and forms the baſis of ſeveral others. A ſmall quantity of the calx of lead is alſo diſſolved, by boiling in the lintſeed oil, which is uſed as paint. It makes the oil dry ſooner, and leave a thicker varniſh on the ſurface of bodies to which it is applied. Oil-paints, in which the coloured calces of lead are employed, are, for this reaſon, the moſt durable pigments. White lead and lintſeed-oil contracts a ſkin on its ſurface which is almoſt impenetrable by any action of the air and weather. Its only defect is, that ſulphurous and putrid ſteams ſoon blacken it. Hence it is that this brilliant white cannot be uſed in water colours in miniature painting.

Lead, either metallic, or in the ſtate of calx, has alſo a ſtrong attraction for ſulphur. Sulphur is added to melted lead, and when mixed with it, readily unites, and forms a compound leſs fuſible than lead, and which in cooling produces a maſs internally cryſtallized into glittering particles, and greatly reſembling one of its ores. It is decompounded with difficulty by uſtulation; more readily and perfectly by iron.

Sulphur acts alſo upon the oxyds of lead, and upon the compounds of theſe with acids, when it is applied in the form of a liquid alkaline ſulphuret. The ſulphur unites with the oxydated lead, and blackens it, or gives it a dark-brown, or blackiſh colour.

This effect is alſo produced by the inflammable air, or ſulphurous hydrogen, that is contained in liquid alkaline ſulphurets, and which ſeparates from them in the form of a fœtid gas, when acids are added to them, or when they are largely diluted with water. The hydrogen gas having, when pure, very little attraction for water, has a tendency to evaporate from ſuch a diluted mixture; and it carries away a ſmall portion of the ſulphur, which, if it meet with any oxyd of lead, is ſure to be attracted by it, and to blacken it. This is the origin of what is called *ſympathetic ink*, or ink that appears by ſympathy. In the courſe of the numberleſs experiments of the alchemiſt on lead, in the fond hope of converting it into ſilver, it appears that none engaged their fancy ſo much as thoſe that were diſguſting. Human urine, human ordure, rotten eggs, and ſuch things, were favourite objects of reſearch, or means of farther inquiry. When the abominable ſmell of hepar ſulphuris was obſerved, hepar ſulphuris was tortured by every alchemiſt in Europe, and its myſterious properties were innumerable. Baſil Valentine diſcovered that rags moiſtened with acetite of lead became black in a few minutes if near hepar ſulphuris, and he made a magical trick by it. If you write with a ſolution of ſaccharum ſaturni, and lay the paper between the firſt pages of a thick book, and put between the laſt pages a leaf of paper that is moiſtened with a ſolution of an arſenical preparation containing hepar ſulphuris, the writing will become legible in a few minutes, which was aſcribed to a certain inexplicable ſympathy between lead and arſenic. Lemery diſcovered that the arſenical preparation was effectual, only becauſe it contained hepar ſulphuris. The hydrogen gas itſelf, independently of the ſulphur which is combined with it, has ſome ſhare in producing this effect, and it is not improbable that the ſulphur alone would not produce it. The hydrogen gas acts by reducing the lead to its metallic ſtate, and thus diſpoſing it to unite the more readily with the ſulphur. Of the power of this gas to reſtore diſſolved metals to their metallic ſtate we have many examples in ſome ingenious experi-

ments made by Mrs. Hulſham. A wet mark made with liquid acetite of lead, when expoſed to the hydrogen gas as it ariſes from iron filings and ſulphuric acid, blackens immediately.

Mrs. Hulſham diſcovered that water muſt be preſent with the metal and acid, otherwiſe the reduction will not ſucceed. The effect of the water probably depends on its attraction for the acid, by which it promotes the ſeparation of the metal, while the hydrogen attracts the oxygen from it. But the preſence of water is not neceſſary to the action of ſulphurated hydrogen gas. The metal is then ſeparated from the acid by the power of two attractions acting at once; the attraction of the hydrogen for the oxygen of the metal, and that of the ſulphur for the metal itſelf.

The ſame effects are alſo produced on the oxyds and ſolutions of biſmuth, and rather more ſtrongly than on thoſe of lead. Pearl white precipitated from the nitrate of biſmuth by the ſolution of cream of tartar, being rubbed on paper, and expoſed to the hydrogen gas, is much more blackened than the ſimilar preparations of lead. And theſe effects enable us to diſcover the preſence of lead in various liquids in which it may happen to be concealed, as in wines eſpecially, and cyder, and in oils and other fluids. The anxiety of the French chemiſts about this matter may be ſeen in the works of Macquer and others.

Cyder made in Devonſhire was formerly liable to this adulteration; but I believe that care is now taken to avoid it in future. It was produced by putty and other preparations of white lead, which were uſed for filling the ſeams, and ſtopping leaks in the preſs-floors and vats. A better conſtruction of them has made this unneceſſary.

Relation of Lead to other Metals.

It will not mix with iron or cobalt, but unites eaſily with all the reſt, and is employed ſometimes to promote the calcination of ſome which are otherwiſe calcinable indeed, but which calcine more quickly

along with the lead. Of this I ſhall point out particular examples hereafter.

The uſeful compounds of this metal with others, are 1*ſt*, Type-founders metal, in which it is the principal ingredient, but mixed with antimony. 2*d*, Organ-pipe metal, in which it is mixed with tin. 3*d*, Pewter, in which tin is the principal metal, but there is commonly ſome lead as an alloy to the tin; commonly too much. Nails made of a compoſition of three parts of tin, two of lead, and one of antimony, are hard enough to be driven into oak without being blunted, and are not ruſted by ſalt water.

Another great uſe of lead is in working of the ores and metallic mixtures containing the precious metals ſilver and gold. In working the ores of thoſe metals, it produces a thinner fuſion of all earthy and vitrifiable matters than any other ſubſtance. In ſuch a thin liquid, the ſmalleſt globule of the precious metal makes its way to the bottom, which it could not do through a more clammy glaſs.

Iron, tin, and all other metals, except copper and platinum, are ſeparated from the gold and ſilver by means of lead, by actually deſtroying them as metals, and reducing them to a thin vitreous ſlag or ſcoria, which is blown off the ſurface of the melted maſs, in the ſame way as litharge is, or is abſorbed by the porous veſſel or teſt in which this ſcorification is performed. The gold or ſilver is left in the veſſel, becauſe it completely reſiſts the action of heat and air, and the ſcorifying power of the lead. The ſcoriæ which are driven off, or imbibed by the teſt, are reduced to metal by pounding and melting it along with inflammable matters.

With regard to the ores of this metal, there is no great variety. There is only one ſpecies found in abundance, the *galæna ſaturni*, which varies a little in its appearance. The richeſt is commonly that which breaks with broad and bright ſurfaces, and into cubical maſſes. Some of the varieties of it break with leſs broad and more irregular ſurfaces, and ſome with ſuch ſmall ones, that the fracture looks more or leſs

like that of ſteel. But though galæna is the principal, and only abundant ore of lead, ſmall quantities of this metal are found in other ſtates in the mines which abound with galæna: For example, 1*ſt*, Lead almoſt pure and metallic. 2*d*, Calx variouſly cryſtallized and combined with fixed air. 3*d*, And ſometimes combined with ſome acids, as in green ore, &c. Some colourleſs cryſtals of this kind contain arſenical acid, and others the ſulphuric.

Treatment of the Ores of Lead to extract the Metal.

If pyrites be mixed with it, the galæna muſt be roaſted. If it be free from pyrites, it may be melted out without roaſting, or roaſted and melted at the ſame time. This is done in this country in very low furnaces, or a ſort of open hearths. In England it is done in reverberatories.

As an article of the materia medica, this metal is reckoned powerful. As an internal medicine, it has an eſtabliſhed character as a moſt powerful aſtringent. It is therefore uſed ſometimes, after all other remedies have failed, in profuſe hemorrhages from the uterus, the lungs, or the ſtomach. But it is not employed, except in caſes which appear otherwiſe deſperate, as it is certainly in itſelf a dangerous remedy. It is well known that the workmen employed in many of the manufactories of lead loſe their health by it, and become objects of compaſſion;—ſuch as thoſe who melt it from its ores, and thoſe who prepare colours from lead, or grind them for the painters. Such perſons are ſeized with obſtinate conſtipation, dreadful griping pains, contractions, and paralytic affections of the legs and arms; and as all comes on very ſlowly, men are not alarmed; and the profits of their employment makes them continue at it till their caſe becomes diſtreſſing, and generally incurable.

Mr. Clutterbuck, of the college of ſurgeons in London, gives an account of a new and ſucceſsful method of treating thoſe affections. His method is to give mercury, which he conſiders as a powerful ſti-

mulant and exciting remedy, and therefore oppoſite to lead, which is powerfully ſedative, and often hurtful, and even mortal, by its ſedative, and weakening benumbing power. A number of caſes are related, in every one of which a cure was completed in ſix weeks at fartheſt. To obviate the coſtiveneſs produced by lead, he uſed calomel; a grain or two every night operated more certainly and eaſily than any other laxative. He alſo removed the palſy of the hands, by continuing the mercury until the mouth was a little affected.

As external applications, however, the preparations of lead are not only ſafe, but in the higheſt degree uſeful and ſalutary. The character it bears in this view, is that of a cooling ſedative anodyne, and diſcutient medicine. A French author, Goulard, wrote two books upon it, in which he ſhews plainly that he is an enthuſiaſt in his opinion of its value; but relates, in a very ſimple and diſtinct manner, caſes which are very ſtriking proofs. He recommends it highly in moſt external inflammations, where there is great pain or heat, and eſpecially in paranychia, phymoſis, and paraphymoſis, buboes, eryſipelas, when tending to mortification; the painful inflammation before mortification; gun-ſhot wounds that are long in healing, and all ill-conditioned ulcers; the hard painful ſwellings, and the ulcerations of womens breaſts; all ſort of fiery eruptions of the ſkin; and itch. In theſe ill-conditioned ulcers, and painful inflammations, its effects are often very remarkable in relieving the patient from pain, and abating the inflammation, and all its ſymptoms; and inducing ſleep,—and changing the ſtate of ulcers for the better in every reſpect, and facilitating the ſeparation or extraction of extraneous bodies from them. In ſome, however, it does not do ſervice; and ſuch are more relieved by relaxing emollient applications. I was informed by a navy ſurgeon, that it ſeldom did ſervice in the caſes of ſailors. A weak ſolution of ſaccharum ſaturni is at preſent found the beſt dreſſing for ſcrophulous ſores or tumours.

Mr. Goulard's preparation is made by boiling litharge two or three

hours in vinegar; but as this muſt be of very uncertain ſtrength, according to the different vinegars employed, we find it more adviſable to uſe ſaccharum ſaturni, diſſolving a ſcruple, or half a drachm, in a bottle of water. This gives a determinate ſtrength, if the water be pure. But it generally becomes milky, in conſequence of ſome muriat or vitriolic ſalt contained in it. This diminiſhes the ſtrength a little.

GENUS XI.—TIN—STANNUM.

This is the lighteſt of all the metals, its ſpecific gravity not exceeding 7,3. The fineſt Engliſh tin when melted does not exceed 7,29. Hammering will bring it to 7,3. Therefore lightneſs muſt be conſidered as a teſt of its purity. It is remarkable that when mixed in due proportion with all other metals, except regulus of antimony, the ſpecific gravity of the mixture is much greater than what ſhould reſult from the weights of the ingredients. Nay, mixed with ſome much heavier than itſelf, the mixture has a greater ſpecific gravity than the heavieſt metal. The tin muſt receive the other metal into its pores, in ſuch a manner as not to increaſe the bulk.

The colour of this metal is very like that of fine ſilver; and it retains its colour and brightneſs in the air better than many others. It has a conſiderable degree of malleability, and it can be hammered into very thin leaves, but it has not enough of that kind of tenacity that fits it for being drawn into wire. When thick pieces of it are bended, it gives a grating ſound, which appears to proceed from ſome deficiency of tenacity, or ſome imperfect union and coheſion of its parts.

It is the moſt fuſible of the metals, and is eaſily melted with a heat conſiderably leſs than the boiling heat of quickſilver; and when large quantities of it are melted, and then allowed to cool and congeal without diſturbance, its parts concrete into oblong angular maſſes or

priſms. This is ſeen moſt diſtinctly when a large maſs or block of pure tin is broken in pieces with the ſtrokes of a large hammer, immediately after it has concreted from a melted ſtate, or rather before the concretion of it is quite completed. It then appears in the form of what is called *grain tin*. We can alſo reduce it to a powder, or to ſmall grains like ſand, by melting it in an iron mortar, and ſtirring the melted tin briſkly and inceſſantly until it be congealed. Thus we get the pulvis ſtanni of the diſpenſatories.

Tin has a ſtrong attraction for oxygen, calcining with a very moderate heat; and from the whiteneſs and infuſibility of the oxyds which it affords, it appears to undergo, in proper circumſtances, an high degree of oxydation, which can even be carried ſo far by the action of the nitric acid as to convert it into a ſort of acid.

The oxyds of tin cannot be melted or vitrified by themſelves, and are even difficultly melted in mixture with other vitrifiable bodies. For this reaſon an oxyd of tin, mixed with the ingredients of glaſs, forms one of the beſt of the white enamels *.

When we diſſolve tin in ſome of the acids, we find that while diſſolving it has ſome degree of power to decompound water.

It can, for example, be diſſolved by digeſtion with ſulphuric acid, a little diluted, in which it diſſolves ſlowly; and while diſſolving it decompounds a little of the water, and produces ſome inflammable air, but far leſs than iron or zinc. The tin is thus ſlightly oxydated as well as diſſolved, or it is combined with a ſmall quantity of oxygen taken from the water. But when it has attracted this ſmall quantity of oxygen, its attraction for more is diminiſhed to that degree that it has not power to decompound any more of the water, although it is capable of attracting a far greater quantity of oxygen when this is

* This, however, cannot be made in perfection without a little lead. A glaſs containing lead may be whitened with tin or arſenic, or diaphoretic antimony: But if the calx of tin be added to a glaſs that was free of lead, it is diſſolved, and becomes tranſparent.

applied to it in a more ſimple ſtate; in the form, for example, of oxygen gas, either pure, or as contained in atmoſpherical air *.

The ſulphuric acid, not diluted, and applied hot, can corrode and diſſolve half its weight of tin, and is at the ſame time changed in part into ſulphurous acid, the diſſolving tin attracting in this caſe from the acid itſelf a part of its oxygen. If the action of the acid be made leſs rapid, by diluting it with a very ſmall proportion of water before it be applied to the tin, a portion of it can be changed into perfect ſulphur, as is the caſe alſo with lead. [" But, largely diluted, it will not " act upon tin." FOURCROY.] †

The nitric acid and tin act on one another in the ſame manner as the ſame acid and the metal of antimony. The tin is not diſſolved, but oxydated to an high degree, by attracting to itſelf the oxygen of the acid. But this action, which is ſlow when we make the experiment with the metal of antimony, is ſudden and violent in the caſe of tin. The acid is violently changed and decompounded; part is changed into nitrous acid; part into nitrous air; and a conſiderable part even into azotic gas.

The oxydation of tin by the nitric acid affords another diſtinct example of the formation of volatile alkali. Tin, as well as iron, decompoſes water,—and we ſee that it decompoſes this acid in a more

* Is this conformable to the general train of chemical phenomena, or even to the particular phenomena in the oxydation of metals? It ſeems to be a doctrinal point, that when once a metal has combined with pure oxygen it is then, and not till then, diſpoſed to combine with more oxygen clogged with another ſubſtance in the form of an acid. Is the oxygen in oxygenous gas more ſimple than in water? It requires, in moſt caſes, a very high temperature to begin the combination of combuſtible bodies with the oxygen in the gaſeous form. EDITOR.

† Is the theory quite perfect here, and in ſome other ſimilar inſtances? Tin diſengages hydrogen by reaſon of its ſtrong attraction for oxygen: Yet if water be added to the ſulphuric acid, and thus afford a more copious and eaſier ſupply of oxygen, the ſulphuric acid is, in this caſe, more deprived of its oxygen than when the water ſupplied it leſs liberally.

EDITOR.

remarkable manner, ſince it extricates pure azotic gas. That the hydrogen of the decompounded water unites with the azote of the acid, appears (in the ſame manner as in the caſe of iron) by adding a cauſtic alkali or lime. This immediately detaches the volatile alkali, and we perceive it by the ſmell, or by the cloud which it forms with the vapour of the muriatic acid. We may uſe, of aquafortis three parts, water five, tin leaf three, and ſlaked lime three. Dr. Auſtin was the contriver of this experiment, having firſt made it in another form, namely, by moiſtening tin leaf with the acid, and rolling it up looſely till it was corroded. He then wetted it with a ſolution of potaſh, which inſtantly detached the volatile alkali.

This experiment, therefore, coincides admirably with the others from which we have acquired the knowledge of the compounded nature of the volatile alkali. And it is the more ſatisfactory, on account of its ſucceeding equally well when made with other metals wh ch have a powerful attraction for oxygen, of which iron is an example *.

The muriatic acid, in its ordinary ſtate, diſſolves tin very well, and in great quantity, eſpecially when aſſiſted with a digeſtive heat. It will diſſolve one-third of its weight. During the diſſolution, ſome inflammable air is produced by the decompoſition of a ſmall part of the water, from which the diſſolving tin attracts the oxygen. And if there be the ſmalleſt quantity of arſenic in the tin, which is often the caſe, it remains undiſſolved in the form of a black matter, which is metallized arſenic.

The ſolvent, however, which has been commonly employed for

* Dr. Black has omitted taking notice of what has been called the *acid of tin*, or *ſtannic acid*, by ſome late chemiſts. It is a ſingular combination of tin with oxygen, firſt obſerved by Mr. Hermſtaedt. A ſolution of tin in muriatic acid, being boiled with nitric acid, which has been diſtilled from manganeſe, till the red fumes have ceaſed, is then diſtilled to dryneſs. The remaining maſs is ſoluble in water, ſaturating thrice its weight. This is called *acid of tin*. It melts by a red heat, and is deprived of its ſolubility and acid taſte,—but long expoſure to the air reſtores theſe properties. EDITOR.

diſſolving this metal is the nitro-muriatic, or aqua regia. It has hitherto been employed by the dyers for producing the ſolution of tin neceſſary for fixing the ſcarlet dye in the cloth dyed with cochineal; and it was univerſally believed, both by the dyers and the philoſophical chemiſts who wrote on the art of dying, that no other ſolution of tin was fit for this purpoſe, and that it was neceſſary for giving the bright red or flame colour to the dye of the cochineal, which when uſed alone, gives only a purpliſh red.

But Dr. Bancroft, who has benefited the world with a moſt valuable treatiſe on the art of dying, has ſhewn that theſe were very great miſtakes. He has ſhewn that the bright and florid colour of the ſcarlet dye is not produced by the ſolution of tin alone, or principally, but by it and a quantity of tartar, which is abſolutely neceſſary in the proceſs, and chiefly by the acid of the tartar. The ſolution of tin and the tartar mutually decompound one another, by a double elective attraction, and a tartrite of tin is produced, which is neceſſary for the effect deſired. And the doctor has ſhewn that a cheaper ſolution of tin than that produced by the nitro-muriatic ſolvent is fitter for this purpoſe. It is made by diſſolving about fourteen ounces of tin, in a mixture of two pounds of the ſtrong ſulphuric acid and three pounds of the muriatic acid. This mixture may be called the *muriatico-ſulphuric* ſolvent. It is a far cheaper ſolvent than the nitro-muriatic employed by dyers; and it diſſolves a much greater proportion of tin.

The nitro-muriatic ſolution of tin is alſo employed for preparing from the ſolution of gold a fine purple or red colour, employed in enamels. For this purpoſe it is neceſſary that the tin in this ſolution, ſhould be as little oxydated as poſſible. This condition is obtained by diſſolving it ſlowly, a little at a time, in an aqua regia compoſed of four parts of aquafortis, and one of muriatic acid, diluted with an equal quantity of vinous ſpirits;—we muſt keep all very cold. When enough of tin has been diſſolved, the liquor has a light yellow colour.

This ſolution muſt be preſerved from communication with the air, both while the tin is diſſolving, and afterwards; for the tin, when diſſolved in any acid, eſpecially in the muriatic, has a powerful attraction for more oxygen, and attracts it very faſt from the vital air of the atmoſphere, and from other bodies. This appears from many facts, and eſpecially from a remarkable one diſcovered by Mr. Woulfe. He found that white arſenic in powder, put into a recent ſolution of tin in muriatic acid, was metallized.

We have another remarkable muriat of tin, viz. the *liquor fumans Libavii.* The French call it the *oxygenated,* or *ſuper-oxygenated muriat of tin.* It has ſeveral remarkable properties, which we have not time to conſider,—and I muſt refer you to Mr. Fourcroy.

To make this preparation, amalgamate the tin with one-fifth of mercury, and triturate with an equal weight of corroſive ſublimate. This mixture, diſtilled with a gentle heat, gives out, firſt an inſipid liquor, and then ſuddenly produces abundance of white vapours, which condenſe into a tranſparent liquor, which emits ſimilar vapours by mere expoſure to the air. I take this to be the muriat of tin overcharged with oxygen; for we have in the retort, beſides an amalgam of tin and mercury, the common muriat of tin in a ſolid form, and needing only a greater heat to volatilize it completely.

Some experiments made by Mr. Adet give us more information concerning the nature of this ſingular muriat, and juſtify my calling it a ſuper-oxygenated muriat of tin. A certain proportion of water, nearly one-third, added to it, cauſes it to become concrete. In their combination, a conſiderable quantity of common air is diſengaged from the water, if it has not been carefully cleared of it before. Heat melts this maſs, and it is then able to diſſolve more tin,—and in this ſolution no inflammable air is diſengaged. Thus ſaturated with tin, the compound will bear a red heat without ſublimation; but vapours ariſe, which are a muriat of tin,—what remains after a ſtrong heat, is a white calx.

From theſe facts it would ſeem, that the compound, ſaturated with the metal, is an ordinary muriat of tin; and the ſmoking liquor of Libavius is an oxygenated muriat, differing from the other as corroſive ſublimate differs from calomel. Mr. Adet's notions about the conſolidating effect of water are ingenious, but are not explanatory; and I think the inferences are not juſtly drawn.

I do not know any remarkable effect of other compound ſalts on tin. Nitre deflagrates with it as with other metals. The vitriolic ſalts are decompoſed by it, and its avidity for oxygen decompoſes the acid, and we have ſulphur. It acts in the ſame manner in decompoſing ſal ammoniac; and we obtain inflammable air by the decompoſition of ſome of the water.

None of the earths exhibit any intereſting phenomena in conjunction with tin.

Sulphur combines with it in a remarkable manner. An ounce of flowers of ſulphur being added to five ounces of tin in fuſion, they form a black compound, much leſs fuſible than the metal. The mixture therefore fixes as ſoon as the chemical union takes place, and the latent heat of both ingredients emerges, and there is a bright incandeſcence, and the maſs ſuddenly catches fire. When the ſulphur is in a much larger proportion, the tin ſeems to deflagrate.

This combination of tin with ſulphur is the baſis of another remarkable preparation, which long amuſed the fancy of the alchemiſts. —I mean *aurum muſivum.*

Aurum muſivum, or *moſaicum*, is made by various proceſſes. The one moſt certain of ſucceſs is the old one of Woulfe. (*Phil. Tranſ.* 1771.) Melt twelve ounces of tin, and add three ounces of mercury; triturate the mixture with ſeven ounces of ſulphur, and three of ſal ammoniac; put the powder into a matraſs and ſet this in the ſand-pot of a furnace deeper than the ſurface of the contents; employ firſt a gentle heat for ſeveral hours, and then raiſe it conſiderably for ſeveral hours more. In the bottom of the veſſel will be found the golden

ſcaly maſs, of a ſlippery texture, like black lead. If the heat has been too great, or too long continued, it gets a dark colour and ſtriated texture; farther up from the heat, we have cinnabar, and a compound or muriat of tin;—a volatile hepar eſcapes. The aurum muſivum contains ſeven parts of tin and five of ſulphur, and conſiderably exceeds half of the materials. The cinnabar is much overcharged with ſulphur. The volatile hepar is but trifling. There is no mercury in the aurum muſivum. This muriatic ſublimate greatly excels all ſolutions of tin for giving a ſcarlet dye. The mercury and ſal ammoniac are not eſſential, but improve the colour remarkably; and aurum muſivum, prepared without mercury, does not make a good amalgam for increaſing the power of an electrical machine, for which the other preparation is very remarkable. Chaptal, however, ſays, that this pigment, as generally prepared, contains almoſt one-ſixth of mercury*.

Tin produces ſome uſeful mixtures with other metals †. Firſt, it is uſeful for tinning iron, and copper, and braſs veſſels. *Tinned plate iron*, or *white iron*, is a moſt uſeful production of art, as it is ſo eaſily wrought. The tin not only adheres to the iron, but penetrates it to a conſiderable depth, and renders it extremely ſoft and ductile, ſo that it can be forced up into any ſhape by the hammer, without cracking, or loſing much of its pliancy.

Fine pewter is a mixture of tin with a ſmall proportion of copper, and zinc, and biſmuth. The copper gives hardneſs; the other two improve the colour.

* *Proceſs for preparing a beautiful Aurum Muſivum.*

Precipitate nitrate of tin by a liquid ſulphat of potaſh. Waſh and dry the precipitate, and mix it with one-fourth of ſal ammoniac, and one-half of ſulphur. Put this mixture into a retort, and give it a ſubliming heat.

† A mixture of tin and lead calcines faſter than any metallic mixture that we know, burning like a dull peat; and the compound calx is more oxydated than either of the metals can be ſingly. Hence the advantage in the admixture of a ſmall quantity of lead with the tin for making white enamel.

A metallic mixture, which has the beautiful whiteneſs of fine ſilver, is made of tin and biſmuth. It is probable that copper or iron may be eaſily tinned with it. I ſuppoſe ſome of the iron work of chariots is whitened with it.

Tin is alſo added to copper in different proportions, to ſerve different purpoſes, which I ſhall mention when I ſpeak of copper.

I have already obſerved that the calx of tin is employed for the compoſition of white enamels. It is a miſtake in the writers on this ſubject to ſay that the pure calx of tin is the proper baſis of this compoſition. It muſt contain a minute portion of lead, or the flux uſed with it muſt contain lead, otherwiſe it will make only a ſemi-tranſparent white. Montamy, who has written the moſt accurately, and indeed excellently, on enamel painting, gives minute directions for the preparation of this article, becauſe it is uſed with almoſt every colour, in order to give to each its proper intenſity. It is a moſt tedious proceſs, ſo that the article muſt bear a very high price. He preſcribes pure tin; but then his *fondant*, or *flux*, with which it is diluted, is *cryſtal d'Angleterre*, which is our flint-glaſs, containing lead. The common white glazing uſed for the cover of Delft ware is a much cheaper compoſition, being merely the calx of pewter carefully made, and often having an admixture of arſenic. Taſſie's medallions are made of this, with a little magneſia,—with flint, and minium, or flint-glaſs, for a flux.

Tin is very rarely produced by nature in its pure and metallic ſtate; and there is no great variety of its ores. Only one kind is found in plenty. And no part of the world abounds with it ſo much as Cornwall. There is an exact regiſter kept there of the produce of the tin-mines, and it appears that the average of 20 years has been about 3000 tons weight a-year.

The component parts of the ore are, calx of tin, and ſome iron, and ſometimes a little arſenic. Being thus compoſed entirely of metallic matter, it is remarkably heavy; and being at the ſame time very hard,

it is the ore which, of all the ores, bears pounding and waſhing beſt, and which remains the longeſt time in the gravel and ſands, and ſoil, of the mountainous countries in which the veins of it are found. In ſuch countries great qnantities of this ore are got by waſhing the ſands and gravel of the brooks, or the ſoil that is near them.

After being well dreſſed, that is, waſhed clean from the matrix or ſand, it is roaſted, and then melted in air-furnaces, or reverberatories, with addition of ſome ſmall coal to promote its reduction to the metallic ſtate. It is afterwards aſſayed, to aſcertain its fineneſs or purity; and a ſtamp is put upon it according to the reſult of the aſſay.

Grain tin may always be accounted pretty pure, becauſe a very ſmall portion of lead, which is the cheapeſt adulteration, and moſt frequently practiſed, deſtroys the tendency of the melted tin to aſſume that particular form. Antimony changes the form, deſtroying the greaſy look of the fracture. Biſmuth changes the cryſtallization ſtill more, and is never mixed for gain.

I find nothing ſo effectual for clearing tin for medicinal uſe from the minute portion of arſenic, which it ſometimes receives from the matrix, as diſtillation with ſal ammoniac. Mercury alſo ſeparates it very well; but a very long and careful trituration with water is neceſſary for cauſing the amalgam to throw out all that it contains.

Tin is uſed, in the practice of medicine, as a remedy to kill worms in the inteſtines: For this purpoſe it is reduced by granulation to a powder like ſand, called *powder of tin.* This powder, however, has been often prepared, not from pure tin, but from pewter: And in the directions given for preparing it, by Dr. Alſton, who firſt recommended it, in the *Edinburgh Medical Eſſays*, we are expreſsly deſired to take *pewter metal.* But common pewter contains a good quantity of lead, and I think I once obſerved colic pains, that appeared to proceed from the uſe of tin powders. I believe this ſeldom happens now, the tin powder being now commonly prepared with pure tin.

It may be propoſed as a queſtion, whether the efficacy of the ori-

ginal powders, in killing or expelling worms, depended on the tin or the lead? The lead, however, never was ſuſpected. But different opinions have been formed on this ſubject. The moſt general one has been, that the powder operates mechanically. If this be juſt, ſand might ſerve the purpoſe better, being leſs heavy, and more eaſily moved by the inteſtines: And I have been told that ſand is ſometimes given to horſes. Mr. Lewis hinted a ſuſpicion that the tin might act by the powers of a ſmall quantity of arſenic contained in it. But late experiments do not ſupport this notion. They go againſt it, and ſhew that commonly tin does not contain arſenic, or ſo very little that it cannot produce its effect. And the truth is, that ſo very little, if any, of the tin is diſſolved or corroded in the inteſtines, that it is impoſſible the very ſmall quantity of arſenic which it has been found to contain ſhould act in any perceptible manner: The opinion therefore of its acting mechanically appears the moſt probable: Or if it be ſuppoſed to act in conſequence of its being corroded or diſſolved, ſome other preparation of it would be preferable.

GENUS XII.—COPPER.

The obvious qualities of this metal are well known.

Of all the metals, copper is the moſt ſuſceptible of condenſation by hammering, or wire-drawing. For this reaſon, it is very difficult to ſay what is its ſpecific gravity. In Muſchenbroeck's voluminous table of ſpecific gravities we have it from 7,243 to 9000. Briſſon ſays that copper melted is 7,788, and when drawn into wire is 8,878. This is much owing to the manner of caſting. Unleſs poured out in a very liquid ſtate, that is, of very great heat, it will not caſt either ſolid or tenacious, but is cavernulous and weak. In its beſt ſtate it ſeems porous. It is conſiderably ſofter when juſt red hot, and bears the hammer. In this ſtate it was employed in the haſty coinage of the Romans; frequently in camp, with the general's die.

It is far more ductile and malleable than any of the metals yet deſcribed, and therefore is conſidered as a more perfect metal. Its tenacity is alſo very great when wire-drawn, exceeding that of all other metals except iron. It reſiſts the injuries of the weather much better than iron, and acquires by time an obſcure gloſſy ſkin, which helps to defend it, like a varniſh. There is a way to give it this ſort of ſuperficial colour by art, It is done by firſt poliſhing it, and then daubing over its poliſhed ſurface the deep red oxyd of iron called colcothar, or Spaniſh brown, diluted with water, after which, the copper is heated to a certain degree, and the colcothar again rubbed off.

Copper, though not much inferior to iron in hardneſs, will not ſtrike fire when violently driven or rubbed on flint, or other hard bodies. This is owing to its being ſo much leſs calcinable, that is, inflammable; ſo that, although when a rag of copper is torn off by the ſtroke, it is perhaps red hot, yet it does not *kindle* and become a ſource of heat to kindle other bodies. Copper is therefore employed in the powder mills for every purpoſe that iron is required for in other works. The hoops of powder caſks, the chizels, mauls, hammers, and even nails, are all made of copper.

It requires a degree of white heat for its fuſion, and in its fluid ſtate has a bluiſh green colour. Melting it ſimply, without any addition, renders it leſs malleable; but when melted with a little charcoal on its ſurface, its malleability is preſerved. When copper is urged by very great heat, it ſmokes; and the ſmoke is found to be metallic copper, (*Mem. Acad. des Sciences*, 1769, *Jan.*)

It has a great capacity for heat, and requires beſides, a great quantity of latent heat to render it fluid. A conſequence of which is, that when melted copper comes into contact with a ſmall quantity of water, or watery humidity, the melted metal communicates heat to it ſo rapidly, and in ſuch immenſe quantity, that dreadful exploſions are often thus produced, by the inſtantaneou schange of the humidity into highly elaſtic vapour. The moſt anxious care is therefore employed,

in founderies of copper, to have the moulds perfectly dry: They are even made red hot for ſome hours before we venture to caſt any large piece of work.

When we chooſe to calcine copper by the action of air and heat alone, this is beſt done by expoſing it to a red heat far inferior to that by which it is melted. The ſurface of it is then gradually changed into a blackiſh cruſt, which is brittle and pulverable, and gives a powder of a deep red colour. This is an oxyd of the metal, which is but little oxydated, and is very eaſily reduced again to pure metallic copper, by the uſual means.

All the ſaline ſubſtances act with great facility on this metal. The more ſimple and active diſſolve it perfectly: The more compounded or milder ſalts corrode it into ruſt.

The ſulphuric acid requires the aſſiſtance of heat to make it act upon copper. Except when made very hot it has not power to diſſolve this metal; and it muſt alſo be applied in its ſtrong ſtate. During its action, part of it is changed into ſulphurous acid, by the loſs of a portion of its oxygen, which is attracted by the copper. And the metal, being thus oxydated, and then combined with the reſt of the acid, aſſumes the form of a whitiſh maſs, which can afterwards be eaſily diſſolved in water, and gives a liquor of a fine blue colour, which admits of large dilution in water, without ſeparation of the acid. From this liquor again we can obtain, by due evaporation, deep blue cryſtals, commonly named *blue vitriol.*

This is, therefore, the third of the compounds which were commonly called *vitriols*, which have been already mentioned in this courſe. The firſt was the ſulphat of iron, commonly named *green vitriol;* the ſecond was the ſulphat of zinc, commonly called *white vitriol;* and this third one, as I ſaid juſt now, is commonly known by the name of *blue vitriol.* There is alſo mentioned, in Mr. Boyle's works, and thoſe of other ancient chemiſts, a vitriol by the name of *Roman vitriol.* This was a mixed one, accidentally formed of the ſul-

phat of iron and ſulphat of copper, cryſtallized together, but containing more copper than iron.

The nitric acid, in the diluted ſtate of aquafortis, diſſolves copper the moſt readily and quickly. The acid becomes very warm, and there is a ſtrong efferveſcence, and production of a great quantity of nitrous air, into which a part of the acid is changed, in conſequence of the abſtraction of oxygen from it by the diſſolving copper. This nitrous air is ſo pure, or nearly pure, that Dr. Prieſtley commonly uſed it in his experiments for trying and comparing the wholeſomeneſs of different airs. It is not, however, quite ſo pure as that produced by diſſolving quickſilver; but copper produces it more conveniently *. The compound formed by the oxydated copper and the remainder of the nitric acid is very ſoluble, and tinges the ſolution of a fine ſky blue. It bears large dilution in diſtilled water, without ſeparation of the acid and metal. By due evaporation, it yields cryſtals of a very deep and rich blue colour, very ſoluble, and even deliqueſcent.

If the cryſtals of the nitrate of copper be bruiſed, and ſlightly moiſtened, and then be haſtily wrapped up in tinfoil, touching it in as much ſurface as poſſible, nitrous fumes immediately come out, the maſs becomes hot, and preſently catches fire, brandiſhing and throwing out deſultory darts of flame and melted tin. It is not at all clear whence does ariſe the great heat in this experiment. The only che-

* Chaptal ſays that when the copper is put into this acid in ſmall pieces, ſo as to preſent an extenſive ſurface, the action is exceedingly violent, the acid is rapidly decompoſed, and after the eruption of much gas, there is a ſudden re-abſorption, and ammonia is produced. This is a curious, and a ſomewhat embarraſſing fact. Whence comes the hydrogen? for we know that a tube of pure copper, red hot, does not decompoſe watery vapour. If, indeed, water be decompoſed, and hydrogen diſengaged, the re-abſorption might be attributed to its combination with the azote diſengaged from the nitrous acid, had we not learned from Dr. Auſtin's experiments that although gaſeous azote will combine with naſcent hydrogen, gaſeous hydrogen will not combine with naſcent azote.

EDITOR.

mical change that we obſerve is a nitrate of tin in the place of a nitrate of copper, and the eruption of nitrous fumes. Some more oxygen ſeems, therefore, to be neceſſary for the new compound; and we ſhould rather have looked for a diminution than an increaſe of heat; unleſs we admit the heat to be produced in the ſame way as when alcohol or ſugar is added to nitric acid.

Paper, moiſtened with a ſolution of this nitrate, when held before the fire, catches fire at a very low temperature,—not ſufficient to melt tin.

Theſe cryſtals are very fuſible, but it is a ſort of watery fuſion they undergo; for they are very retentive of water; and if we increaſe the heat a little too high, the acid begins to evaporate, and carries away a ſmall portion of the copper.

The muriatic acid diſſolves this metal ſlowly. The colour of the ſolution is at firſt dark brown, but becomes green by keeping. Sympathetic, or rather changeable ink, of Mr. Macquer, is prepared from this ſolution.

The ſolution, when duly diluted, has a light blue colour, and when ſpread on paper, exhibits the ſame hue as long as any moiſture adheres to it. But when ſlowly dried before the fire, and allowed to attract the moiſture again, it returns to its former ſtate of an almoſt imperceptible blue. In order to inſure the diſappearance when cold, dip a pencil in the ſolution (very weak) of muriat of lime. Paſs this over the copper ſolution,—it will not decompoſe it, but, by attracting moiſture, will cauſe the colour to vaniſh almoſt entirely. Care muſt be taken with this, and indeed with all thoſe ſympathetic inks, not to let the paper become too hot. This ſcorches that part on which the ſolution is ſpread, and makes it a permanent brown.

The ſcales of copper, formed by calcination, exhibit nearly the ſame appearances in ſolution in this acid. A recent and brown ſolution of the ſcales, if largely diluted with water, depoſits part of the copper in the form of a white precipitate, ſuper-ſaturated with cop-

per. This white precipitate, if immediately diſſolved in freſh acid, gives a brown ſolution, which, like the brown ſolution of copper, or of the ſcales, becomes green, if expoſed to the air; abſorbing oxygen from the atmoſphere, becoming more calcined, and more ſoluble.

Hence we may conclude, 1*ſt*, that the ſcales are very moderately calcined; and that metallic copper undergoes nearly the ſame degree of calcination, when forming a brown ſolution in the muriatic acid. 2*d*, That copper cannot be more calcined by mere heat and air, its ſurface being already neutralized. But if the copper be divided by ſolution, and expoſed ſimply to the air, it abſorbs more oxygen; and the ſolution becomes green.

The vegetable acids do not diſſolve copper readily in its metallic ſtate. The confectioners have obſerved that acids, ſyrups, and pickles, made with vegetable acids, do not acquire a bad taſte from copper veſſels, if only boiled quickly, and not allowed to cool in them, or to remain after cooling. It is only when we apply ſuch acids to copper in the ſtate of an oxyd, that they have power to diſſolve it. But an oxyd is very ſoon formed, if theſe acids, or any ſaline ſubſtance whatever, is applied to this metal, while air is allowed at the ſame time to act on it; a green or blue ruſt is ſoon formed, which is moſtly an oxyd of this metal, in an highly oxydated ſtate, and very ſoluble in vegetable acids. And the reaſon why theſe may be haſtily boiled in clean copper veſſels without being tainted is, that there is not time nor ſufficient action of the air for the formation of an oxyd *.

* This co-operation of the air, in the ſlow ſolutions, or rather oxydations of copper, is unqueſtionable, and is the ſource of ſome very curious appearances, which have long puzzled the chemiſts, but are now pretty well underſtood. It is not peculiar to copper, but its effects in the caſe of copper are more remarkable. But it is ſurely a difficulty in the theory. It is unlike the whole train of chemical phenomena, that a partial combination with any particular ſubſtance ſhould increaſe the diſpoſition to combine with more. There ſtill lurks ſome yet undiſcovered agent.

EDITOR.

Verdigriſe is an acidulous oxyd or ruſt of copper, produced by art, prepared much in the ſame manner as the ſaccharum ſaturni. It is alſo prepared in a coarſer way, by taking what remains in the wine-preſs, after the muſt has been entirely ſqueezed from the grapes, adding ſome ſoured wine, and ſtratifying this mixture with plates of copper. As the huſks grow ſour, the copper is corroded; and after ſome weeks of this treatment, the ſaline cruſt is beaten off by the hammer. This coarſe preparation is then diſſolved in weak vinegar, with the addition of ſome more copper; and laſtly the cryſtals are purifyed in the uſual manner.

This ſubſtance diſſolves readily in diſtilled vinegar, and gives a liquor of a deep green, which being evaporated, gives cryſtals of the ſame colour; but the powder of them is bright and elegant, like that of all ſemi-tranſparent bodies. Hence it is uſed by painters, though they find it corroſive. The name they give it is very improper,—*diſtilled verdigriſe*.

All theſe compounds of copper with acids, when they are thrown into the fire, or mixed with flaming fuel, give a green or blue colour to the flame, and noxious fumes.

If we deſire to decompound theſe compounds of copper with acids, we can effect the decompoſition of ſome of them by heat alone, others can ſcarcely be decompounded without the aid of an elective attraction.

The one which is the moſt eaſily decompounded by heat alone, is the acetite of copper. This muſt be done by diſtillation of the dry materials, that we may obtain the acid as concentrated as poſſible. As a dry powder cannot communicate the heat ſo quickly and perfectly to the interior parts, as a fluid body can do, this diſtillation always deſtroys ſome of the acetous acid. The firſt part of the produce is tainted with a ſmall portion of copper, which gives it a green colour; and before the production of acid vapours is much abated, there is a very ſenſible empyreuma. We therefore do not obtain nearly the

whole of the acid in a ſtate which can be purified. The taint of copper is eaſily removed by a rectification; but the empyreumatic ſmell cannot be taken from a conſiderable portion, obtained about the end of the diſtillation, when the bottom of the retort is even red hot. If this be left out, we obtain the acid in a very concentrated ſtate, having a very pungent, but agreeable odour; inferior however to that which may be obtained, by a careful dephlegmation of vinegar concentrated by freezing.

From ſixteen ounces of cryſtallized verdigriſe we may obtain three ounces of water, and ſix and a half of acid, of which five and a half are (after rectification) free from copper and from empyreuma. There is a reſiduum of five ounces and three quarters, and a loſs of nearly an ounce. This loſs is ſuſtained before the ſtrong acid comes over.

Mr. Berthollet has ſhewn that it is a more powerful acid, and has a ſtronger attraction for alkalis than common vinegar; and that this is in conſequence of its receiving oxygen from the oxyd of copper, which is reduced nearly to its metallic ſtate during the diſtillation, and is generally a pyrophorus. *(See Note 29. at the end of the Volume.)*

Of the other acids, only the nitric acid can eaſily and perfectly be ſeparated by heat *; the ſulphuric acid difficultly. The muriatic acid is not ſeparable by heat alone, but rather renders the copper volatile along with itſelf.

But alkaline ſalts, and alkaline earths, precipitate the copper; and ſome of the precipitations deſerve notice.

1ſt, Lime-water is ſometimes employed to precipitate copper from ſome of its ſolutions, and gives a precipitate, which is an oxyd of the

* If the acid ſo obtained be condenſed in a receiver containing a ſolution of cauſtic foſſil alkali, it forms a nitrate of ſoda, differing exceedingly from that formed by diſſolving ſoda in nitric acid. I could not bring it into a good ſtate of cryſtallization; nor would it form cubical cryſtals at any rate, but coaleſced in flakes, which felt ſlippery and ſoft.

metal, combined with a ſmall quantity of the lime, of a pleaſant light blue colour, and is called *verditer*. It is employed by the painters. The French call it *cendres blues*,—blue aſhes. The copper is firſt precipitated exactly by quicklime, and then from ſeven to ten *per cent.* of quicklime is ground with the calx and a little water.

2*dly*, Mr. Scheele has taught us another way of precipitating the copper, by which we obtain another colour uſeful for painters *.

When alkalis in their ordinary ſtate are uſed, the copper is precipitated in form of a very pale or whitiſh-green oxyd, which can be diſſolved again by adding more of the alkali than what is neceſſary to ſaturate the acid; the ſuperfluous alkali acting on the metal as a ſolvent. This is moſt remarkable when we uſe the volatile alkali.

The volatile alkali has this power of a ſolvent with reſpect to all the purer oxyds or ruſts of copper, and acts, though more ſlowly, even on the metal in its metallic ſtate. And the deepneſs or richneſs of the colour is ſuch, that it enables us to detect a very ſmall quantity of copper in any mixture. One-hundredth of a grain will ſenſibly tinge a pound of water.

The action of ammonia on copper, or its oxyds, preſents a very remarkable phenomenon. If a ſolution of cauſtic volatile alkali be

* Mr. Scheele's proceſs is nearly as follows.—Diſſolve two pounds of the blue vitriol in a copper kettle, over the fire, in about ſix quarts of pure water; diſſolve in another veſſel two pounds of dry potaſh, and eleven ounces of pulverized arſenic, (N. B. what is ſold ready pulverized is generally adulterated with gypſum) in two quarts of water, alſo over the fire; when all is diſſolved, ſtrain the ſolution through linen.

Pour this arſenical ſolution into the ſolution of blue vitriol, ſtirring the mixture all the while with a wooden ſpatula; let the mixture ſtand quiet ſome hours, that the green colour may ſettle; then pour off the clear liquid, and edulcorate the ſediment with repeated hot waters. At laſt the green pigment is obtained by draining it through a linen cloth, hanging looſely between four ſticks; and then it is dried on blotting paper, or a chalk ſtone. By this proceſs we obtain one pound ſix ounces of the powder.

The moſt careful edulcoration is neceſſary; for if it retain any of the alkali, it will not work with oil as a paint. It makes a very elegant and lively green. EDITOR.

poured on copper filings, we have in a ſhort time a ſolution of a beautiful blue. If a bottle be filled quite full of the ſolution of alkali, and we put in ſome filings, and immediately put in the ſtopple, we ſhall not have any ſenſible blue colour till after a very long while. When ammonia is in a veſſel not quite full, and has acquired this blue colour, it loſes it by long keeping when the veſſel is all the while cloſe; but if we open it, the blue colour begins to appear at the ſurface, and in time it penetrates to the bottom. Cloſing the veſſel cauſes it to loſe the colour completely after ſome time; and it will again return when the veſſel is left open. And this may be repeated ſeveral times before it becomes permanently blue. Chemiſts attempt to explain theſe appearances, by obſerving, 1*ſt*, That when the alkali has become ſaturated with copper, the ſolution is permanently blue; 2*d*, The ſolubility in alkali increaſes, as the metal is more oxydated, to a certain degree; 3*d*, The action of the air contributes greatly to the oxydation, when there is ſomething at hand ready to take up the oxyd. Therefore the firſt ſolution is that of a very minute portion of copper at the ſurface; all below has ſuch an exceſs of alkali that it is colourleſs. When the veſſel is now cloſed, the copper, which is more abundantly diſſolved at the ſurface, diffuſes, and is again combined with an exceſs of alkali, and grows colourleſs. Now open the veſſel,—the ſuperficial parts become more oxydated, a greater quantity is diſſolved, and the colour reappears, and will reach the bottom, if the veſſel be kept open; if not, the copper again diffuſes till the ſolution is again equable, with exceſs of alkali, and colourleſs. This may go on till *all* the alkali is ſaturated, when the colour becomes permanent.

Alkalis, therefore, have the power to diſſolve copper, as well as to precipitate it from acids. They ſhew this power alſo when applied to it in the way of fuſion, but act more eaſily on the oxyds than on the pure metal. And not only the alkalis alone, but any glaſs that contains them, acts upon thoſe oxyds, and diſſolves a certain quantity of them. The glaſs is thus coloured by the copper combined with

it, and the colours it aſſumes are either tranſparent blues or greens, more or leſs ſimilar to the colours of the ſolutions of copper; or, when a great quantity of this metal is combined with the glaſs, the colour of the mixture is an opaque red. The beautiful greens that are ſeen in the figures and foliage on the glazings of pottery are generally done with copper.

Another precipitation of copper from its ſolutions, which deſerves notice, is the precipitation by iron. The copper is precipitated in its metallic form, as in many other caſes of the precipitation of one metal by another; the iron attracting both the acid and oxygen at the ſame time. This manner of precipitating the copper is practiſed in ſome places with the waters of mineral ſprings, which flow through veins or mines of copper ore, and which contain a ſmall quantity of blue vitriol diſſolved in them. This is in ſome places ſo abundant, that they are treated for the copper they contain, by putting old iron into the gutters in which they run,—the cupreous mud which ſettles on it is collected and reduced to metal in the uſual manner, by a very ſmall quantity of inflammable matter and flux.

Sulphur unites readily and ſtrongly with copper, when they are properly mixed, and made to act on one another with the aſſiſtance of heat; and while they are uniting, a quantity of heat is extricated from them, which ſuddenly produces in the mixture a remarkable and bright degree of ignition.

Some very remarkable experiments were made by the Dutch chemiſts Van Trooſtwyck, Deiman, and others, which occaſioned conſiderable ſurpriſe, and led ſome to call in queſtion the theory of combuſtion publiſhed by Mr. Lavoiſier. It appeared that bodies could burn without the abſorption of oxygen. For the heat and incandeſcence produced in theſe experiments were ſo remarkable as to be miſtaken for a real inflammation in cloſe veſſels. When three parts of copper are mixed with one of ſulphur, and are rammed into a ſmall narrow-mouthed phial, and expoſed to a heat gradually raiſed to red-

neſs, the mixture ſwells, and then, almoſt in a moment, becomes luminous all over, and burſts out into a violent flame. Zinc and ſulphur require a ſtronger heat, and give a brighter flame: So do iron and ſulphur. This experiment ſucceeds equally well in *vacuo*, in carbonic acid, in azotic, or in hydrogenous gas. (*See Exper. Phyſ. et Chym. par V. Trooſtwyck, Deiman, &c. Amſterd. tom.* iii.) But ſince theſe facts have been more carefully examined, it appears that it is not an inflammation or combuſtion, but merely an incandeſcence, ariſing from a copious emergence of latent heat,—the compounds are totally different from thoſe formed by real combuſtion. They have not, however, been ſufficiently examined, though very intereſting *.

The compound, when the parts of it are completely united, is a dark leaden-coloured maſs, which is quite brittle, not in the leaſt malleable; and I ſuſpect that a great part of that heat which was extricated from it was the latent heat, which gave toughneſs and malleability to the metal in its ſeparate ſtate. The ſulphur is not eaſily burnt out of this compound. There is leſs difficulty in freeing iron from ſulphur, although iron is ſuppoſed to have, and has in reality, a ſtronger attraction for ſulphur than copper has. The reaſon why the ſulphur is not ſo eaſily evaporated from copper is, that this metal is not ſo calcinable by heat as iron, and can be calcined only to a very moderate degree. In this moderately calcined ſtate, it retains the ſulphur ſtrongly, and parts with it ſlowly; whereas iron, when joined with ſulphur, forms a compound, in which the iron is very eaſily calcinable, and to a high

* I think that it may be inferred from this, and many ſimilar facts which have already come in our way, that the oxygenous gas is not the ſole ſource of the heat and light which emerge in the combuſtion of bodies. In the union of ſulphur with dry filings of iron, copper, zinc, lead, tin, ſilver, and with running mercury, there is no oxygenous gas, nor gas of any kind in action, and yet a very great deal of heat and light eſcape from the bodies. Not to call this combuſtion is, at beſt, philoſophical affectation and faſtidiouſneſs. It is not oxydation,—nor is the union of azotic gas with oxygen combuſtion. So to miſname the one is ignorance, and ſo to miſname the other is pedantry.

EDITOR.

degree. It has a ſtrong attraction for oxygen or vital air; and when the iron is highly calcined, its attraction for ſulphur or the ſulphuric acid, is greatly diminiſhed,—the calces of metals which are highly calcined, having in general but little attraction for ſulphur or acids. But although we cannot ſo eaſily and quickly burn and evaporate ſulphur from copper, it may be burnt out and evaporated from it by a ſlow and ſkilful uſtulation or calcining proceſs, continued for ſome time. The firſt effect of it is to change the ſulphur into acid, which remains adhering to the copper, and makes it ſoluble in water into a blue liquor, from which blue vitriol may be obtained by cryſtallization; or if, inſtead of diſſolving the calcined matter in water, we roaſt it further with a ſtronger heat, we can evaporate the ſulphuric acid, and have at laſt an oxyd of copper, nearly in a pure ſtate.

Some of the other inflammable ſubſtances alſo ſhew an attraction for copper or its oxyds. Several of the aromatic oils can diſſolve ſo much as to receive a deep green tincture from it. Some of the unctuous oils alſo, eſpecially when rancid, eaſily diſſolve ſo much copper, or ruſt of copper, as is ſufficient to tinge them blue or green *. In the tallow of common candles, a ſmall quantity of verdigriſe is added to improve the colour.

The uſeful compounds of copper with other metals are, 1*ſt*, *paak fong*, or *paak tong*, the white copper of the Chineſe, which is ſuppoſed to be copper alloyed with nickel. And when zinc is added to the compound, it reſembles ſilver by its colour. An imitation of ſilver is alſo attempted with copper and arſenic. 2*dly*, The metallic compounds of which braſs guns are caſt, and bells, and the mirrors of reflecting teleſcopes, are copper or braſs, mixed with different proportions of tin. A ſmall proportion of the tin gives the copper a yellowiſh colour, and makes it very hard and inflexible, although it has ſtill ſufficient toughneſs, and great ſtrength. This compoſition is therefore employed in caſting what are called braſs guns. A larger

* Hence the terrible effects produced by copper veſſels employed in cookery.

proportion makes it very elaſtic, though leſs tough and ſtrong. This is uſed for bells. A ſtill larger proportion of the tin forms a denſe white compound, which receives a very perfect poliſh, but is quite inflexible and brittle as glaſs. This is uſed for mirrors of teleſcopes. The beſt compoſition for the mirrors of teleſcopes was diſcovered by the induſtry of Mr. Edwards, and publiſhed in the *Nautical Almanack* for the year 1787. You will find an account of it in *Nicholſon's Chemiſtry*, where he mentions the combinations of copper with other metals. The ancients made uſe of tin very much, as an alloy of copper, and in the compoſition of their braſs, for their arms and cutting inſtruments, which required great hardneſs. It is deficient in toughneſs: But this is conſiderably improved, as I am informed, by paſſing it between the rollers of the flatting mill.

There is ſomething curious in the proceſs for whitening pins. It is commonly believed that this is done by mercury. But it is a coating with tin, incomparably more durable.

Copper, diſſolved in any acid whatever, is precipitated completely by tin. Yet in this proceſs the tin is precipitated by the copper. The effect depends on the attraction of pure or metallic copper for pure or metallic tin. The tin is firſt diſſolved by a mixed ſolvent, which contains ſome tartar; during which diſſolution, the tin is ſlightly oxydated: And this ſolution alone does not whiten copper in the leaſt. But if freſh tin, or a ſmall quantity of iron, be added while it is boiled with the copper, the freſh tin, or iron, by their attraction for oxygen, deoxydate the diſſolved tin, or deoxydate a part of the water, the hydrogen of which deoxydates the diſſolved tin, which, before it has time to form coherent particles by itſelf, is attracted by the ſurface of the copper, and adheres to it. Mr. Gadolin tinned gold in this manner, although the ſolvent he uſed could not act in the leaſt upon gold.

Of ſolvents for ſuch a purpoſe, when a bright and ſhining ſurface is required, rather than an high degree of whiteneſs, the ſolution of

tartar is to be preferred. The ſolution of alum gives merely an exquiſite whiteneſs; but it is a dead white. If tartar and common ſalt are added to the alum, they take off the deadneſs of the white, and give ſome poliſh and brightneſs. One part of white tartar, two of alum, and two of common ſalt, form the beſt ſolvent. The ſolvent ſhould not diſſolve any of the copper. If any part of the copper ſhould be diſſolved, it would fruſtrate the proceſs. *(Nicholſon's Dict. p. 947.)*

This metal is alſo alloyed with zinc, to form pinchbeck, braſs, and ſimilor. Copper, mixed with zinc, in the proportion of two parts of copper to one of zinc, forms braſs, which has a light greeniſh yellow colour, and when made red hot, is made quite brittle. I have already deſcribed the proceſs for making this compound by cementation. But with equal parts of zinc, the copper forms a Bath metal, or ſimilor, which is malleable when heated, like iron. And if a little iron, or caſt ſteel be added to this compound, the mixture proves as malleable when heated as iron, and as ſtrong and difficult to bend and break when cold. They are, therefore, making trial of it now for bolts in building ſhips of war. Copper, in the proportion of three or four parts to one of zinc, makes pinchbeck. Similor has a rich yellow colour, and in conſequence of its ſoftneſs and malleability when hot, is formed into all ſorts of goods at Birmingham, by ſtamping or coining.

Copper is alſo the moſt fit metal to be uſed as an alloy to ſilver and gold, to give theſe metals ſtiffneſs and hardneſs, without diminiſhing their toughneſs too much.

The relation of lead to copper is ſomewhat particular. Copper does not mix with lead, unleſs the lead be heated to the boiling or ſcorifying degree. The copper then ſinks in, and is diſſolved very quickly; but if allowed to cool, ſeparates in ſome meaſure, ſo that the maſs becomes like ſand and water. When copper and lead are mixed, they are therefore eaſily ſeparable; firſt by eliquation, then by ſkimming the lead, which will make it ſufficiently pure from the

copper; and as the copper ſtill retains a little lead, this is worked off by ſcorification. Copper is ſeparated from other coarſer metals in general by ſcorification, eſpecially with lead.

Natural Hiſtory of Copper.

Copper is frequently found in its metallic ſtate, and nearly pure, in the form of plates or fibres, or branched maſſes, or irregular lumps, intangled in the matrix of the vein. In the inland parts of North America, there are rich veins containing copper in this form. It abounds in the ſame ſtate in ſome of the iſlands that are to the weſt of North America; and is found more or leſs in many other parts of the world.

Profeſſor Robiſon told me that an old officer in the Ruſſian ſervice, who was with Captain Bering in the firſt voyage from Kamtſchatka to America, informed him that on the beach in Bering's iſland there lay an immenſe quantity of metal, rounded like pebbles by the waſhing of the ſea, which were all malleable copper. He thought that many ſhips might be loaded with it. This has probably been a volcanic production; for Kamtſchatka, and the whole cluſter of iſlands between it and America, ſeem to have been raiſed by the ſame cauſe. I alſo ſuſpect that it was rather an ore, or an oxyd, than the native metal which was ſeen at Bering's iſland. The weſtern diſtrict of the Siberian mines contains many horizontal ſtrata of copper gravel, in which are found plants and trunks of trees (all exotic) completely penetrated by the copper.

But it occurs much more frequently in the form of ores, of which there is a conſiderable variety and abundance. Angleſea contains the richeſt bed of copper perhaps in the world; and of late years, yields about twenty-five thouſand tons of metal annually. The vein is about ſeventy feet thick.

In taking a curſory, but comprehenſive view of the ores, they may be diſtinguiſhed into three principal kinds:

1*ſt*, The natural oxyds of copper.
2*d*, The gray ores of this metal.
3*d*, The yellow ores.

The moſt remarkable natural oxyds are of four varieties:

1. The deep red oxyd of copper,—*minera vitrea rubra.*
2. The blue oxyd,—*minera lazurea.*
3. The green oxyd,—*minera viridis.*
4. The fibrous green oxyd, named *malachites.*

The ſecond general ſection of the ores, the gray ores, comprehends thoſe in which the copper is combined with ſulphur, arſenic, and other metals, but is itſelf the moſt abundant ingredient in the compound. Iron is generally contained in theſe ores, and often ſome ſilver. If the ſilver is in ſuch quantity that the extraction of it is a profitable buſineſs, they are often named *ſilver ores.*

The third general ſection comprehends the yellow ores, or copper pyrites. In theſe, the copper is not the moſt abundant metal, iron being preſent in greater quantity, together with much ſulphur, and often arſenic; but the copper is in ſuch quantity, that it is the moſt valuable ingredient, and is the only one which gives value to theſe ores. They have a yellow colour and metallic luſtre, like that of braſs, or a little reſembling that of the common pyrites, which contains iron and ſulphur only, but are eaſily diſtinguiſhable from the common pyrites by obvious differences. The common pyrites is ſo hard that a knife or file makes no impreſſion on it; and it ſcratches glaſs, and ſtrikes fire with ſteel. The copper pyrites is ſo ſoft that a knife eaſily makes impreſſion on it, and ſcrapes or ſcratches the ſurface of it. They are alſo remarkably different in colour. The yellow of the common pyrites is pale; that of the copper pyrites is deeper and richer, often ſimilar to that of gold, and it is liable to a ſort of tarniſh, which produces the priſmatic colours on its ſurface, as they are produced on the ſurface of ſeveral metals by the action of heat.

We can be ſatisfied by an eaſy experiment, whether or not a py-

rite contains copper. We need only to beat a ſmall quantity of it to powder, and uſtulate or roaſt this powder with a low degree of red heat, by which we ſhall burn out the ſulphur, or the greater part of it. If we then apply liquid ammonia to the remaining matter, this will immediately produce a deep blue ſolution, if there is copper contained in it.

As the gray and yellow ores of copper are moſt abundant, and are found to contain, although in various proportions, the greateſt quantity of ſulphur, arſenic, and iron, I ſhall firſt deſcribe the proceſs by which the copper is extracted from theſe. To effect this ſeparation, both labour and time are required, on account of the ſtrong adheſion of ſome of theſe ſubſtances to the copper.

The firſt operations which the richer ores of this kind undergo, are repeated roaſtings with a moderate heat, and ſubſequent fuſions with a ſtronger one. Thus the greater part of the ſulphur and arſenic are gradually diſſipated, and the iron is calcined and ſcorified, or vitrified with the earthy and ſtony matter that is intermixed with the ore, eſpecially if this ſtony matter is quartz. This ſiliceous ſtone, when it happens to be mixed with the ore in moderate quantity, greatly promotes and facilitates the extraction of the copper, by its having a remarkable diſpoſition to unite with calcined iron, and to be vitrified with it, or converted into ſcoriæ or ſlag. And when a rich copper ore is brangled with quartz, ſo much that it cannot be pounded and waſhed clean without conſiderable loſs, it is uſual to melt the whole, with addition of common pyrites; the iron of which being very calcinable, ſoon vitrifies along with the quartz, or brings it into fuſion, while the ſulphur, or a part of it, joining itſelf to the copper ore, increaſes its fuſibility, and makes it more readily ſubſide from the ſcoriæ. This manner of melting the poor or ſtony copper ores, is called *crude melting*, or *crude fuſion*; and the product of the operation is afterwards treated as a rich ore of copper, by repeated roaſtings and melting proceſſes. In England, the firſt roaſting of the copper pyrites is performed in ſuch a manner, that a great part of the ſulphur

is ſaved, by a contrivance which I deſcribed not long ſince, when I gave you the natural hiſtory of ſulphur. The ſubſequent roaſtings and meltings are performed in low reverberatories, or ovens of conſiderable length, heated with flame. This is kept playing on the ſurface of the metal; and there are tranſverſe ribs in the arch of the oven, which obſtruct the direct paſſage of the flame to the chimney, and beat it down on the melting matter. The flame carries with it abundance of unconſumed vapour and ſmoke, which robs the ore of its oxygen, and leaves it in a metallic ſtate. It is ſtirred from time to time, through a hole at the far end of the oven, immediately below the upright chimney; thus no cold air gets to the metal, to calcine it or cool the furnace. A tap hole is opened at the ſide, at the loweſt part of the bed; the metal flows out, with the ſcoriæ floating above it, and then falls into a mould, which gives it the form of a triangular priſm. When this mould is full, the metal runs over into another, which it ſeldom fills, but has ſlag above it; and the reſt of the ſlag runs over into a receptacle large enough to hold it all. I muſt content myſelf with this ſhort deſcription; for it would employ a ſeſſion to deſcribe theſe things minutely.

On the Continent, a variety of furnaces are employed, which you may ſee deſcribed and repreſented in copperplates, in Schlutter's work on metallurgy, which was tranſlated into French by M. Hellot.

When the copper is, by theſe operations, freed from its impurities to a certain degree, but ſtill retains a ſmall quantity of them, it is called *black copper*, and is very deficient in malleability; and often has not at all the colour of copper. If it contain ſilver, ſome lead is added to it in this ſtate, and is then ſeparated from it again by eliquation. In this proceſs, all the lead melts and ſweats out of the copper, and runs off, except a ſmall portion, which remains inherent in the ſpongy maſs of the copper. The ſilver is taken out by the lead, which has a ſtrong attraction for it. The copper then undergoes the laſt operation, which is the refinement of it; and the ſmall portion of lead which it retains, facilitates this proceſs, and makes it more perfect.

The hearth or furnace for refining copper contains two tons, or two tons and a half, of copper, which is refined at once. The diameter of the melted metal is about three feet, the depth about two feet. A little water is ſprinkled upon it from a broom. This is diſſipated in vapour in an inſtant, and the ſurface of the copper is frozen. This ſkin is lifted off immediately with a pair of tongs, and thrown into a tub of cold water. Its under ſurface is of a bright roſe colour, and ſomewhat rough and glittering by a ſort of cryſtallization. It is called *roſe copper*. This operation is continued till the whole of the copper is thus lifted off in ſkins.

The refined copper requires water to be poured on about forty times before the laſt of it is conſolidated. This is a clear evidence of the great quantity of latent heat which melted copper contains, for the firſt water muſt cool the metal to its congealing point, otherwiſe no part of it would be congealed. All the ſubſequent additions of water, therefore, are neceſſary to extract the latent heat only, the perceptible heat continuing the ſame.

We have only now to add further, that in ſome of the ſtates or conditions in which copper is found, it does not need all theſe operations to fit it for uſe. Such of it as is found in its metallic ſtate, and nearly pure, requires only the operation of refinement. And the ores in which it is in the ſtate of an oxyd, need only to be firſt reduced to the metallic ſtate, and then refined.

The very poor yellow ores alſo, which ſometimes contain no more than three, or four, or five pound of copper in the hundred weight, are often treated in a particular manner. They are firſt uſtulated with a very low red heat, during which operation the metallic matter is oxydated, and the ſulphur burnt, and changed into ſulphuric acid, and part of it evaporated; but a part remains adherent to the oxyd of copper; and water being afterwards applied to the uſtulated matter, a ſolution of blue vitriol is formed, which is either evaporated afterwards and cryſtallized, to be ſold in that ſtate, or inſtead of evaporat-

ing the liquor, pieces of old iron are put into it, and allowed to remain until the copper is precipitated on them, which is then collected and melted into a maſs.

The preparations of copper for medicinal uſe, are,

Cuprum ammoniatum;—Edin.

Pilulæ cæruleæ;—Edin.

For external uſe,

Ærugo;—Edin.

Unguentum ex ærugine;—Edin.

Vitriolum cæruleum;—Edin.

Aqua ſtyptica;—Edin.

Aqua vitriolica cærulea;—Lond.

Aqua ſapphirina;—Edin. and Lond.

Ens veneris, formerly in the Edin. Pharm.

SILVER AND GOLD.

We have now conſidered all the metals which have been commonly known and uſed, except ſilver and gold.

Theſe two have been long diſtinguiſhed by the chemiſts from the reſt of the metals, by the title of the more noble or perfect metals, on account of their having the metallic properties, malleability, ductility, and durability, or incorruptibility, in a much more eminent degree than the other metals.

I ſhall firſt conſider the qualities by which they thus excel other metals, and afterwards thoſe which diſtinguiſh theſe two.

Firſt, therefore, their amazing ductility and malleability are qualities in which they far ſurpaſs all other metals. By experiments made upon ſilver, it appears that a ſingle grain, which hardly exceeds in bulk the head of an ordinary pin, may be drawn out into a wire near nine feet long. And further, this wire, or any part of it, can be beaten out by hammering, into a thin plate or leaf one inch broad. It can therefore be made to cover 108 ſquare inches.

Of the ductility and extenſibility of gold, we have examples in the

different branches of the art of gilding, or the art of covering the ſurface of other ſubſtances with gold. One way is with what is called *gold leaf*. And the art of beating out the gold into leaf, is very well and accurately deſcribed by Mr. Lewis. The degree of extenſion and thinneſs to which gold is brought in common gold leaf is aſtoniſhing. It is plain from the moſt evident and ſatisfactory calculations, that the thickneſs of gold leaf is not the $\frac{1}{200,000}$th of an inch. But gold is much more extended in manufacturing gold lace. What is called gold lace is not woven of gold wire, but of ſilver; the ſurface of which only is covered with a film of gold. To make the wire, a thick cylinder of ſilver, weighing forty-eight ounces, has its ſurface covered with one ounce of gold, and is then drawn out into wire ſo fine that ſix feet weigh only one grain. It is then flatted and twiſted round ſilk thread, &c. While the ſilver is thus extended, the gold is extended along with it, ſo as to cover the whole ſurface of the ſilver. The wire, if examined with a microſcope, does not ſhew the ſmalleſt atom of the ſilver uncovered at its ſurface, although the gold is only one-forty-ninth part of its weight, and leſs than the one-eigthtieth of its bulk. (I find it to be the one-eighty-ſixth of its bulk). But this proportion of gold to the ſilver is much greater than what is barely neceſſary for covering or coating the wire. It is ſufficient for giving it ſuch a coat of gold as will bear ſome wearing before the ſilver appears. Mr. Reaumur had the curioſity to get ſome wire drawn with ſuch a thin coat of gold, that there was in his wire only one part of gold to 360 of ſilver. It was drawn to the fineneſs of ſix feet to each grain, and then was flattened between the poliſhed ſteel rollers, which gave it a breadth of one-forty-eighth of an inch, and extended it in length one-fourth.

When our calculations end in ſuch numbers as theſe, we loſe all diſtinct comprehenſion of our ſubject. In order to underſtand the thinneſs of the gold on ſuch gilt wires a little more clearly, I thought it worth while to compare it with the thickneſs of paper, in this manner:

——It would take 14,000,000 of films of gold, like that on ſome gilt wire, to make up the thickneſs of one inch. *Quæritur.*—What thickneſs would 14,000,000 leaves of common printing paper make up? *Anſwer.*—1262½ yards, or near three-fourths of a mile. The thickneſs of the gold on Mr Reaumur's gilt wire, therefore, bore the ſame proportion to one inch, that the thickneſs of a ſingle leaf of printing paper does to three-fourths of a mile nearly, or wanting fifty-eight yards.

Another eminent quality of theſe metals I ſaid, is their durability, or the power they have to retain their metallic form, and remain unchanged, though expoſed in circumſtances, and to the action of bodies, which produce great changes in other metals. One example of this we have in the difficulty of calcining them. They cannot be calcined by the ordinary action of heat and air, by which other metals are calcined, nor by that of nitre, nor with the aſſiſtance of lead. In a violent heat, they remain perfectly metallic and unchanged. Mr. Boyle expoſed ſome ſilver and gold in ſeparate veſſels to the fire of a glaſs-houſe furnace one month. The gold was neither changed nor diminiſhed in weight. The ſilver was unchanged, but diminiſhed by one-twelfth. Kunkel, making the ſame experiment, found the ſilver diminiſhed only one-ſixtieth; and when he repeated it with the ſame bit of ſilver, there was no diminution; from which he concludes, that the diminution in the firſt experiment was occaſioned by impurity. Cramer alſo atteſts the truth of theſe facts from his own experience. It is ſaid, however, by Fourcroy, that Mr. Macquer, by expoſing the ſame ſilver in a porcelain crucible twenty times to the fires in which porcelain was baked, found it changed at laſt into an olive-coloured vitrified matter, which is ſuppoſed to have been a calcined and vitrified ſilver. I do not however find this fact in Mr. Macquer's own writings, though he relates ſome experiments which he and other members of the Academy of Sciences made, by expoſing ſilver and gold to intenſe heats, produced by means of the beſt burning glaſſes

in France. In theſe experiments, theſe metals were in part volatilized, or emitted viſible vapours. Theſe vapours were formed by the metal in an uncalcined ſtate, as appeared plain from their condenſation on the ſurface of ſilver or gold. After a long continuation of theſe experiments, a very ſmall quantity of vitrified matter was formed, but Mr. Macquer juſtly doubts whether it was ſimply a part of the metal calcined. It is poſſible, however, that by mixing theſe metals with others, and expoſing ſuch mixtures to mild calcining heats, continued for a long time, ſome degree of calcination might be effected. But if they ſhould undergo a ſlight degree of calcination by ſuch a proceſs, a ſtronger heat alone makes them immediately reſume their pure and metallic form *.

When nitre is applied to ſilver or gold in a ſtrong fire, provided theſe metals are pure, there is no deflagration or calcination of the metal. The nitre evaporates without producing any effect.

Neither can they be calcined with the aſſiſtance of lead. Lead is often employed to promote the calcination or ſcorification of other metals, or metallic ſubſtances; and its power depends on two particulars. 1*ſt*, The diſpoſition which mixtures of metals have to calcine more eaſily and quickly than the metals in their ſeparate ſtate. 2*dly*, The great fuſibility and diſſolving power of the calx of lead. For when another metal, which produces an unfuſible calx, is calcined by itſelf, its ſurface is ſoon covered over with a cruſt of its calx, which defends it more or leſs from the further action of the air, and occaſions the calcination to go on afterwards ſlowly and with difficulty. But, if to ſuch metal we add a certain proportion of lead, the maſs is diſpoſed to calcine faſter, in conſequence of its being a mixture of metals. And the calx of the lead diſſolves and liquefies the other calx, and occaſions it to flow off continually from the ſurface of the

* The alluſion, therefore, in the Bible, to this quality of the precious metal, to illuſtrate the triumph of a good heart over misfortune, is peculiarly beautiful; and, as this is to be ſeen in the book of Job, the diſcovery muſt be very ancient. EDITOR.

melted metallic maſs towards the ſides, ſo as to leave this ſurface expoſed to the conſtant action of the air; and thus the calcination, or ſcorification, as it is rather called in this caſe, goes on much faſter.

But when we make this experiment with ſilver or gold, there is no calcination or ſcorification of either of thoſe metals. They mix eaſily with lead in the fire; and when this mixture is expoſed to a proper heat and the action of the air, the lead alone is calcined, or ſcorified, and is gradually thrown out of the melted metal; for a calx and a metal cannot mix together. But all this time, the ſilver and gold remain unchanged, and will be found pure and undiminiſhed in quantity, after all the lead is ſeparated from them by the ſcorifying proceſs. The eighth part of an ounce, or even a ſmaller quantity of either of theſe metals, contained in one hundred weight of lead, may be ſeparated from it by this proceſs.

In conſequence of their power to remain uncalcined in ſuch proceſſes, ſilver and gold are often refined or purified from the admixture of other metals by nitre or by lead.

Theſe metals are purified with nitre, by ſimply mixing it with them, and melting. It conſumes the baſe metal, bringing it to the top in a ſcoria, which is eaſily worked off with a little lead. If they are much contaminated, it is uſual to melt them with lead, which takes to itſelf the greateſt part of all the other metals. The mixture is ſeparated from the gold and ſilver by eliquation; and they are then treated with the nitre.

The purification by lead is uſually called *cupellation*, from the ſort of veſſel in which it is performed. The cupel is a very flat cup, but of great thickneſs, made of bone aſhes burnt to a perfect whiteneſs. Theſe veſſels are formed by filling a ſtrong braſs mould with the aſhes, previouſly damped a little. The depth of the mould is conſiderably greater than the intended thickneſs of the cupel, becauſe it is neceſſary that all the materials be put in at once, and afterwards compreſſed by a piece of ſteel like a peſtle, with ſtrong blows of a ham-

mer. If there has not been enough, any addition would form a layer which would afterwards ſeparate in the heat. The face of the peſtle muſt have nearly the convexity of a watch glaſs, and muſt be well poliſhed.

The gold or ſilver is mixed with lead that is known to contain none of either of theſe metals. They are then ſubjected to a ſtrong heat under a muffle, and to the action of a free current of freſh air. This calcines the lead, and along with it the baſer metals, converting them into a thin glaſs, which is abſorbed by the cupel as it forms. The operation is known to be finiſhed, when the laſt film of lead quits the ſurface of the button of gold or ſilver, which in an inſtant grows reſplendent. This is called its *fulguration* or *coruſcation*. The practice with large quantities of metal differs from the above only in this, that the glaſs of lead, inſtead of being abſorbed by the cupel, is blown off by bellows. The lead is got from the cupels again (which are expenſive) by beating them to coarſe powder, and reducing the lead with flux and charcoal duſt.

In conſidering theſe properties of ſilver and gold, we might perhaps be inclined to conclude that they muſt be quite different in their nature from the other metals, ſince we do not perceive in them that affinity with the inflammable ſubſtances, which is ſo obvious and remarkable in the other metals *. But when we ſtudy their other qua-

* Is not this affinity, and their perfect inflammability, diſtinctly ſeen in their diſſipation by the electrical flaſh? They exhibit all the appearances of heat and light, and they are diſſipated in ſmoke, which has a very peculiar and diſagreeable ſmell, different in each metal.

This ſmoke ſhould be examined. The diſſipation ſhould be made in water, which would enable us to collect it, or form ſome judgment by the changes which it produces in that fluid. When the combuſtion (for I muſt give it this name) is effected between two plates of glaſs, (even the pureſt and freeſt from metallic admixture) ſome of the gold or ſilver is incorporated with it. We know that metal and glaſs will not unite, though their oxyds unite perfectly. Theſe facts have not been ſufficiently attended to. If it be thus exploded when ſurrounded by azotic gas, whence comes the light and heat?

EDITOR.

lities,—thoſe which they ſhew in mixture with acids,—we plainly perceive that they have a cloſe affinity and ſimilarity to the other metals, and are at bottom of the ſame nature: For we can calcine or oxydate them by means of ſome of the acids,—and they produce the ſame changes on theſe acids that are produced on them by other metals. Both ſilver and gold, for example, can be oxydated by the nitric acid, and they convert a part of it into nitrous air. And ſilver can alſo be oxydated by the ſulphuric acid, and converts a part of it into ſulphurous acid, or ſulphur.

It therefore appears that they are of the ſame nature with the other metals, and differ from them chiefly by being more difficultly oxydated, having leſs attraction for oxygen, and reſiſting completely ſome of the agents, by which this change is eaſily produced on the other metals. And, when we do bring them into a calcined ſtate by particular proceſſes, they are capable of reſuming their metallic form by the ſimple action of heat on them, which expels the oxygen in the form of vital air, without their requiring the aſſiſtance of any inflammable matter to attract it from them, as it is attracted by charcoal and ſome other inflammable ſubſtances in the reduction of moſt other metallic oxyds.

Theſe are the qualities by which ſilver and gold differ from the other metals already deſcribed. We ſhall now take a view of the qualities peculiar to each of theſe two metals.

GENUS XIII.—SILVER.

The appearance of this metal is too well known to need any deſcription. Its ſpecific gravity is nearly 10,5 or 10,47.

It is never liable to have ruſt formed on it, but it becomes tarniſhed if it be not frequently cleaned; that is, the ſurface of it becomes dark-coloured, as if it had been ſmoked, and ſometimes almoſt black. This happens the moſt certainly, and in the ſhorteſt time, when the ſilver

is expoſed to the vapours of ſulphur, or ſulphurous gas. And putrid vapours from rotten animal or vegetable ſubſtances (eggs eſpecially) produce alſo the ſame effect on it. Late obſervations, indeed, have ſhewn that ſuch putrid vapours frequently contain ſulphur diſſolved in them. Inflammable air alone is ſaid alſo to tarniſh ſilver, and to give to the ſurface of it a purple hue. This ſometimes accumulates on the ſurface of ſilver to ſuch a degree as to form a ſcale, which may be detached, and is found to be a compound of ſilver and ſulphur.

Plate, when thus tarniſhed, may be cleaned by ſoap and water, but more perfectly by ſoot and vinegar. A ſolution in water of the camæleon minerale, or nitre alkalized by manganeſe, does it in the completeſt manner.

The metal is melted by a bright red heat, and when in fuſion, has exactly the appearance that pure quickſilver has, reflecting with an equally bright ſurface the objects around it.

While it is congealing from a melted ſtate, it is liable to form ſuddenly protuberances from its ſurface, which are ſometimes branched, and are named the vegetations of fine ſilver. Their formation is accompanied with a remarkable incandeſcence, or ſudden increaſe of ignition in the congealing ſilver, which incandeſcence is named *coruſcation*, and happens in the congealing of very ſmall quantities of melted ſilver, although no vegetations are formed on its ſurface. But theſe vegetations are ſcarcely ever formed when the quantity of the congealing ſilver is very ſmall. The cauſe of their formation appears to be a power which ſilver has, as well as many other bodies, to retain the latent heat which gives it fluidity, although it be cooled to a degree conſiderably lower than its proper congealing point. And this happens chiefly when it is cooling ſlowly, and without being diſturbed. At laſt, however, the latent heat ſuddenly breaks out, or emerges from a part of the fluid ſilver, and aſſumes the form of ſenſible heat, which produces the incandeſcence; and that part of the metal from which it is extricated, being at the ſurface, ſuddenly congeals. Thus a thin

cruſt of ſilver is inſtantly formed on the ſurface of the maſs. But this ſudden formation of the ſolid cruſt being attended with the increaſe of ſenſible heat, the fluid ſilver within the cruſt is expanded, and burſts through the cruſt in one or two places, ſtarting up in one or more protuberances, which ſuddenly congeal while they are riſing, and in congealing frequently throw out lateral protuberances. And thus are formed the branched figures, like cauliflowers, which are ſometimes produced, and are preſerved by the curious.

Moſt of the active ſalts may be combined with ſilver in one way or another. Sulphuric acid acts only when ſtrong, and boiling hot. Sulphurous acid and ſulphur are produced. The ſalt formed is of little ſolubility, except it contain abundance of the acid.

Diluted nitric acid is the beſt ſolvent of ſilver. It diſſolves it with moderate efferveſcence, during which the metal is oxydated, by attracting oxygen from a part of the acid; and that part of the acid is changed into very pure nitrous air; the reſt unites with the oxydated ſilver, to form nitrate of ſilver. The ſolution of pure ſilver is greeniſh at firſt, a common phenomenon in the ſolutions by this acid, which decompoſe the acid in part; but in a little while it is colourleſs. If it remain green, the ſilver has been tainted with copper. This ſolution bears dilution in pure water, and ſtains hair, bones, and many woods a deep and laſting black; or if weak, a brown. It gives a permanent ſtain even to ſtones; as marbles, agates, and jaſpers. This ſtain does not appear unleſs the bodies be expoſed ſome time to the light of day. The way to ſee this effect of the ſun's light in producing the ſtain, is to dip a bit of chalk or marble into the ſolution of ſilver. If we then keep it in darkneſs, it will remain white; but if any part of it be expoſed to the light of the ſun, that part becomes black in a ſhort time *. Thoſe bodies to which the ſolution is thus applied, attract the acid from the calcined ſilver, while at the ſame time this metal is re-

* And, which is remarkable, it is much more ſtained by the blue and violet light than by the red and yellow, which are much more luminous and heating. EDITOR.

ſtored to its metallic ſtate, or made to approach to that ſtate by the action of the light, which expels from the calx a quantity of vital air. This effect of light, in this and ſome other ſimilar examples, is well known by experience; but we do not clearly underſtand how it is produced. We can imagine that the light joins itſelf to the metal, and expels the air from it. Others think that it joins itſelf to the air, or oxygenous principle, and reſtores to it the aëreal form, or gives it elaſticity to fly off from the metal. In conſequence of this quality of the nitrate of ſilver, it is employed for ſtaining hair brown, and for ſtamping cambrics, and lawns, and ſtaining marbles, jaſpers, &c.

By evaporation, the nitrate of ſilver is reduced to cryſtals, which are very corroſive. They melt like nitre, and they may be moulded into ſmall cylindrical pieces, called *lunar cauſtic*, uſed by ſurgeons as an eſcharotic, and to corrode fungous excreſcences.

This nitrate is perhaps the moſt powerful antiſeptic known. Meat impregnated with it ſo as to acquire a ſenſible taſte, though never ſo ſlight, will not putrefy even in a warm place. In 12000 times its weight of water, it will preſerve it from putrefaction for ever; and it will ſeparate in a few minutes by throwing in a pinch of common ſalt.

The muriatic acid is the moſt ſtrongly attracted by ſilver, and will ſeparate it from every other acid; but it has very little power to act while the ſilver is in its pure and metallic ſtate. The ſilver muſt be ſomehow oxydated to prepare it for joining with this acid. The uſual way is, to take the ſolution of ſilver in aquafortis, in which the ſilver has received oxygen from the acid. If we add muriatic acid to this ſolution, the ſilver inſtantly quits the nitric acid to join with the muriatic, and with this laſt forms a compound nearly inſoluble in water. It therefore ſubſides like a curd or coagulum; and this effect is produced, not only by the pure muriatic acid, but by any ſaline compound whatever which contains it; ſuch as muriat of ſoda, muriat of ammonia, and all other muriatic compounds, a double exchange tak-

ing place. This compound, when waſhed, to free it from the ſaline liquid, and dried, is properly called *muriat of ſilver* by the French chemiſts. It contains $\frac{5}{21}$ of acid, and has ſome remarkable properties; as,

1ſt, It is inſoluble in water to that degree, that the moſt minute quantity of muriatic acid, or of common ſalt, or any other ſaline compound whatever that contains muriatic acid, can be diſcovered in water by adding the nitrate of ſilver.

2dly, In the ſame manner as the nitrate of ſilver, it is changed in its colour, and ſome other properties, by the light of the ſun, or the light of day. We have an opportunity of ſeeing this, if we take two portions of it new made, and keep one of them in a dark place, while the other is expoſed to the light. The one kept in the dark will continue white and unchanged; the other will aſſume a bluiſh, or dove colour, and in it ſome of the ſilver will be reſtored to its pure and metallic ſtate. This has often occaſioned great embarraſſment in the examination of mineral waters. After having indicated the preſence of muriatic acid, by growing milky all over when ſet by, they have become brown, and the chemiſt was made to ſuſpect the exiſtence of ſome other taint in the water, and led into a long and fruitleſs inveſtigation to find out what it was. It was the change produced by light in the lunar ſalt floating all over the fluid. The teſt of this is, that if a portion of the milky ſolution be ſet by in the dark, its colour will not change. Nor will this ſalt, perfectly dry and white, change its colour in air that is alſo perfectly dry, although acceſſible to light. In an experiment made by Mr. Scheele, ſome of it being expoſed to the light, with a large quantity of water covering it, or mixed with it, the ſilver was reſtored to its pure metallic ſtate, and the muriatic acid which was before combined with it, was found in the water which had attracted it. The evidence for this was unqueſtionable. Nitric acid, being poured on the edulcorated black muriat, took up all the black part of it, leaving the reſt white. When ſome of the liquor

which had been decanted from the black muriat, was dropped into this ſolution, as alſo into another ſolution of ſilver in nitric acid, a muriat was immediately formed.

Mr. Berthollet ſays that this ſalt, expoſed and coloured in the ſun, emits oxygenous gas very copiouſly, and that this alſo happens when the nitrate of ſilver blackens by the action of light under water. But Scheele alſo remarks, that if nitric acid be poured on the muriat, it does not blacken. The cauſe of all theſe changes is not very clearly underſtood. The action of the ſun's light ſeems to expel oxygen from the ſolution. If this be taken from the acid, it leaves it in the ſtate of common muriatic acid, unable to diſſolve metallic ſilver; but the preſence of a little nitrous acid ſupplies this, (itſelf becoming fuming) and thus prevents the deoxygenation of the muriatic, and the reappearance of metallic ſilver.

3*dly*, It is fuſible and volatile, and after fuſion aſſumes a horny flexible appearance, which has occaſioned it to be called *luna cornea*.

Mr. Beaumé, however, denies that luna cornea has any flexibility. Indeed it has but little, being commonly ſhivery, and full of tranſverſe cracks, ariſing from its ſhrinking faſter in cooling than the ſubſtance to which it adheres. Kunkel, however, imagined that this is the ſubſtance of which a cup was made which an artiſt preſented to one of the Roman emperors. He threw it on the ground, and the fine tranſparent glaſs cup did not break, but was dimpled by the fall. The artiſt took it up, and putting it again to rights, returned it to the emperor. It was therefore, ſays Kunkel, a malleable glaſs; and he propoſes the manufacture as a chemical problem, declaring that he was in poſſeſſion of the ſecret. The whole is in all probability a fiction, too eaſily credited by Pliny or Solinus, who were but indifferent chemiſts. At any rate, luna cornea would make but a poor figure as a glaſs.

This ſubſtance contains the ſilver in a very pure ſtate. The muriatic acid precipitates no metals from its acid ſolutions, but ſilver,

mercury, and lead. Copper, which may have reſiſted the cupellation with lead, is thus retained in the acid. This method, therefore, is frequently employed for purifying ſilver. It requires ſome art, however, to ſeparate it without loſs from the muriatic acid. They are not ſeparated by a low red heat; for the compound partly eſcapes in fumes united with the acid, and partly runs through the veſſel. It muſt be ground with an equal weight of fixed alkali, and bedded and covered with the ſame in the crucible. It is then obtained in a metallic form, and of the higheſt purity *.

Sulphuric acid alſo, added to the nitrate of ſilver, ſeparates the nitric acid, and is joined to the ſilver in its place, forming a ſulphat of ſilver. If the quantity of the ſulphuric acid is ſmall, or moderate, a great part of the ſulphat of ſilver is precipitated, or ſeparates from the fluid by a haſty cryſtallization; the ſulphat of ſilver, when not ſuper-ſaturated with acid, being much leſs ſoluble in water than the nitrate. But if abundance of ſulphuric acid be added, the ſilver is ſuper-ſaturated with acid, and forms a much more ſoluble compound, which does not precipitate. It has been uſual, however, to attempt to purify aquafortis by adding to it a ſmall quantity of nitrate of ſilver; for if there be a little of muriatic acid in the aquafortis, it is ſure to form a muriat of ſilver, which precipitates. And if a little of the ſulphuric acid were preſent, it was ſuppoſed that this alſo would form an inſoluble compound with a part of the ſilver, and alſo fall down. But this is a miſtake; and the only way to have aquafortis perfectly pure is to add a little of the nitrate of ſilver to it, and diſtil it. Thus the ſmall quantity of both the muriat and ſulphat of ſilver which had been formed, remain in the retort, along with ſome of the nitrate of ſilver, when it is more than ſufficient for ſeparating the two acids.

* I obſerve it ſaid, though I do not recollect by whom, that this muriat, dried and triturated with calx of tin, catches fire.

EDITOR.

In theſe different ways can ſilver be combined with the greater number of the ſimpler ſalts; even with the vegetable acids of wine, of ſorrel, and of tartar. This was firſt done by Margraaf, in the ſame way that I mentioned as followed by him with mercury, namely, by applying the acid to an oxyd of ſilver.

I ſhall now inform you how it may be recovered in its pure metallic ſtate. It is from its ſolution in aquafortis that we have moſt frequent occaſion to recover ſilver; this metal being often diſſolved in aquafortis to ſeparate it from gold.

The recovery of the ſilver from aquafortis may be effected by different means; but there is but one method that is commonly practiſed, on account of its being convenient, effectual, and quick. This method is to precipitate the ſilver by copper. The copper attracts from the ſilver both the acid and the oxygen. The ſilver concretes in its metallic ſtate on the ſurface of the copper, and cryſtallizes into a thick downy covering, which, when viewed with a magnifying glaſs, or with young eyes, is ſeen to reſemble in form a thick foliage of vegetables, or the down of feathers. The way to ſee this cryſtallization the moſt diſtinctly, is to drop ſome of this ſolution on a plate of glaſs a little concave, and then to put a bit of copper in the midſt of it. We ſhall ſee a ſilver fringe form all around it in a minute; and this will continue to increaſe by ramifications in all directions till the whole ſilver is precipitated.

This forms one of the moſt agreeable objects for microſcopic obſervation. A ſingle drop of diluted ſolution being placed before the microſcope, and a particle of copper made to touch its margin, we ſhall obſerve a ſtem ariſe immediately, protruding its branches by ſtarts; and in five minutes, the little buſh occupies the whole field of the inſtrument. *(See Note 30. at the end of the Volume.)*

Clock dials are ſilver-waſhed in this way. The diſſolved nitrate of ſilver is applied to them, along with a mixture of the ſame with a

quantity of common ſalt and tartar. They are then dried, and rubbed with a ſoft linen cloth, and immediately varniſhed.

While ſilver is thus precipitated by copper, a ſmall portion of the copper is ſaid to unite with the precipitated ſilver; but it is a very ſmall one indeed, and ſuch as produces no inconvenience in buſineſs. If edulcorated and rediſſolved in nitric acid, the ſolution becomes perfectly colourleſs; a ſufficient proof of the purity and fitneſs for the moſt nice experiments.

Quickſilver has alſo been uſed ſometimes for precipitating the ſilver; but the difference of their attraction for the acid is ſo little, that the precipitation is ſlow and indiſtinct,—they rather mix in a thick ſolution. The ſeparation of the ſilver by quickſilver, when managed in a particular way, is attended with ſome amuſing appearances.

Into a nitrate, formed by one ounce of ſilver and pure nitric acid, not greatly diluted, but afterwards diluted with twenty ounces of water, put two ounces of mercury. The ſilver cryſtallizes as it ſeparates from the acid, forming beautiful ramifications reſembling broom. It is called the *tree of Diana*. It requires thirty or forty days, and the moſt undiſturbed repoſe. Much more expeditious proceſſes, but inferior in beauty, have been publiſhed by Homberg, Beaumé, and others*. The ſucceſs depends upon the proportion of the mercury to the ſilver, and the ſtrength and ſtate of the ſolution.

I ſaid that ſilver happens moſt frequently to be combined with the nitric acid. Sometimes too it is combined with the muriatic acid, by adding common ſalt to the ſolution of the ſilver in nitric acid. A muriat of ſilver is inſtantly formed by a double exchange, and when this muriat of ſilver is properly waſhed, and the ſilver recovered from

* Beaumé's proceſs is to mix two ſaturated ſolutions of ſilver and mercury,—to dilute the mixture with diſtilled water, and to add a bit of amalgam. If a ſkeleton of a buſh be made of glaſs, and ſet up in the mixture, and ſmeared over with as much amalgam as can be made to ſtick to it, the ramifications will ſoon cover it, and make the toy very pretty.

EDITOR.

it, we have it in the pureſt poſſible ſtate.—It is recovered from this compound, as I have already obſerved, by grinding it with fixed foſſil alkali, and expoſing it to a melting heat, bedded in this alkali, and covered with it. It is of great conſequence to employ the alkali in a cauſtic ſtate. I find that much leſs heat ſuffices for the fuſion, which is a great advantage, becauſe a very ſmall exceſs of heat volatilizes the lunar muriat; whereas, by this precaution, I have always recovered the ſilver without any perceptible loſs.

Silver is eaſily ſeparated from vegetable acids, or from alkalis, when it happens to be combined with thoſe ſalts, which is never except in the way of experiment. Heat alone is ſufficient to deſtroy the vegetable acid, and to diſſipate the volatile alkali. And the fixed alkalis are ſeparated merely by being melted.

The ſulphuric acid is ſeparated, and the ſilver recovered from it, by fuſion with pure fixed alkali. The cauſtic alkali is the fitteſt.

The combination of ſilver with the volatile alkali has ſome very ſurpriſing properties, firſt obſerved, I believe, by Mr. Berthollet, who preſcribed the following proceſs.——Let ſilver be precipitated from a ſolution in pale nitric acid by quicklime. The calx is then to be ſeparated by decantation, and carefully dried for two or three days, by expoſure to the *light* and air. When this is ſtirred and mixed with volatile alkali, it ſeparates in form of a black powder. Decant the liquor, and allow the powder to dry in the air. This powder, if touched in the ſmalleſt degree, ſo as to preſs it againſt the veſſel, and often, if merely parted ſo as to break a grain, explodes with aſtoniſhing violence, daſhing the veſſel to pieces. It far exceeds gunpowder, or aurum fulminans, and requires no heat, the moſt trifling agitation or friction being ſufficient,—even though produced by a drop of water falling into it. We dare not attempt to incloſe it in a bottle, and it muſt remain in the diſh in which it was prepared. We ſhould never attempt to explode more than a grain at once.

The volatile alkali employed in preparing this powder, being expoſed to ebullition in a ſmall matraſs, cryſtallized on cooling. When one of the cryſtals was touched under the liquid, in order to ſeparate it from the glaſs, the whole exploded and beat every thing to pieces.

Mr. Berthollet conſiders this as a looſe compound of oxygen, ſilver, hydrogen and azote, having their double affinities ſo nearly balanced, that the ſlighteſt alteration of temperature, or even of that poſition of ingredients which produces the equilibrium of affinities, is enough to diſturb this tottering equilibrium, in ſuch a manner, that the ſuperiority ſhall incline to that ſide which produces the union of the oxygen and hydrogen. The azote of the volatile alkali is diſengaged, and the ſilver is reduced, and water is formed. The exploſion is produced therefore by the azote, and from the vapour into which the water is changed in the very inſtant of its formation *.

This metal can alſo be joined with earthy bodies in vitrifications; and the colour which it gives to glaſs is a beautiful yellow. It is accordingly uſed to produce that colour in enamels, and the art of ſtaining glaſs. And when more of the ſilver is uſed, the colour is deepened to a blood red, eſpecially with luna cornea, which has been expoſed to the light. But the colours thus given to glaſſes by ſilver are liable to change by over-heat. Leaf ſilver applied to common glaſs or plates, and made red hot with them, penetrates into them, or is

* The explanation is ingenious. But even in this eaſy caſe, we are not yet ſufficiently acquainted with the forces which tend to continue the old aſſemblage, and thoſe which tend to the production of the new, to be able to give an explanation on which the mind can reſt with confidence. Were we certain that theſe are really the only forces in action, we could ſay, from the fact, that theſe are the prevalent forces which unite the oxygen and hydrogen. But this is all *poſt factum*, and we are ignorant of the ſource from which the heat is to be drawn. The new doctrines conſtantly hold forth the oxygen gas as the great ſource of all the heat which appears in combuſtion. Now in the preſent caſe, the oxygen is in the liquid or ſolid form already, and has none to beſtow. Nor do we know any thing of the capacity of the azote for the heat. Beſides, this is not a caſe of double affinity. The ſilver and azote are not united. The phenomenon is by no means explained on eſtabliſhed principles. EDITOR.

diſſolved, tinging them of a deep yellow colour. The loweſt red heat is ſufficient, and the moſt proper is ſuch as will not ſpoil in the leaſt any impreſſion which the glaſs may have received before. A ſtronger heat produces a dull dirty colour, and a degree of opacity. All degrees of it may be perceived in the diſſipation of a ſtripe of ſilver leaf in a ſtrong electrical ſhock. The beſt proceſs for this elegant enamel is as follows: Take glaſs of litharge three parts, flint in groſs powder one part. Pour on this a ſolution of one-twentieth of its weight of ſilver. Stir the mixture till very uniform, and then dry it, carefully avoiding all duſt of an inflammable or combuſtible nature. Melt it and pour it out. Grind it into a very fine powder. This is applied to the porcelain previouſly heated, and the ignition is continued under a muffle till it melts, which is obſerved by its gliſtening. The piece is taken out, and while continued red hot, it is expoſed to the ſmoky flame of burning vegetables, which brings out the beautiful colour. (*Lewis' notes on Neuman, p.* 51.)

Sulphur may eaſily be combined with this metal in the uſual manner, and produces a compound of a colour like lead, but duller, and ſomewhat ſoft and malleable. It is more fuſible than ſilver. This compoſition ſo much reſembles the *minera argenti capillaris*, that it is frequently impoſed on collectors of ores as natural, by forming it on fragments of ſpar, and other uſual matrices of ſuch ores, and by conducting the refrigeration in a particular manner, which cauſes it in the moment of congelation to dart up ſlender capillary filaments, which congeal like a bruſh on its ſurface. The ſulphur is ſeparable by uſtulation. Many other metals alſo attract the ſulphur, as lead, iron, and others.

From experiments made by mixing it with other metals, it appears that all the other metals will readily mix with ſilver. Mercury amalgamates moſt readily, even in the palm of the hand, and their union produces a very ſenſible heat. Nickel will not unite with it, and is, I think, the only metal which it rejects. Lead has a ſtrong attraction

for it, and will abſorb the ſilver from iron or copper. All of them diminiſh its malleability greatly, except gold and copper. Tin does it moſt. A moderate quantity of copper does not change its colour much, but increaſes its hardneſs a little, in which quality it is rather deficient when quite pure. Hence copper is commonly added, and the quantity regulated by law to form the alloy, is about one-twelfth or one-thirteenth. Silver mixed with this proportion of copper is called ſterling or ſtandard ſilver. Nicholſon ſays (on what authority I know not) that our ſtandard admits but one-ſixteenth of copper, that is, one part of copper to fifteen of ſilver.

When ſilver is mixed or alloyed with other metals, and we wiſh to ſeparate them, this is done by different proceſſes. The art of doing it completely has been ſtudied with great attention, on account of the value of this metal, which often happens to be mixed with other metals in their ores, and on other occaſions. The proceſs is different, according to the nature of the metal combined with the ſilver. Thus it is ſeparated,

1. From quickſilver; 1*ſt*, by expreſſion, and 2*dly*, by heat.

2. From all, except gold or platina, by ſcorification and cupellation with lead, or by nitre. It is ſeparated at Birmingham from plated copper, by boiling the plates in ſtrong ſulphuric acid, to which has been added one-tenth of its weight of nitre. The acid acts *more readily only* upon the ſilver than the copper, and the plates are taken out when this is thought to be effected. The ſilver is obtained in the form of a white precipitate, and the copper with which it is ſtill tainted is eaſily ſeparated by cupellation.

3. From gold by aquafortis, or aqua regia. This proceſs is called the *departing*. Mr. Tillet, of the Academy of Sciences, conſidered this proceſs by order of Government, with great care, and has publiſhed very valuable memoirs on the ſubject; and to him I muſt refer you, becauſe a proper account of the proceſs, ſhewing the propriety of its different parts, would take up a great deal of our time, without

much addition to chemical ſcience. Aquafortis, or aqua regia, is employed according as the ſilver or gold exceeds in quantity.

Theſe are the methods followed in practice to ſeparate it from the metals and from gold; and they bring it to as great a degree of purity as is ever needed for common uſe. But theſe methods do not render it perfectly pure. Scorification with lead, or calcination by nitre, leaves a little copper in it. And in ſeparating it from gold by aquafortis, ſome of the copper employed for precipitating it from the acid, joins itſelf to the precipitated ſilver. Or if we ſeparate it from gold by aqua regia, ſome gold is left in it.

But the proceſs by which it is reduced to the moſt perfect purity, is by firſt purging it of all the coarſer metals by cupellation with lead, or by melting it with nitre, and then making it into muriat of ſilver, and reducing it. Thus any gold which might have been in it, or any minute quantity of copper which the lead might have left, is ſeparated from it. *(Vide Cramer.)*

Natural Hiſtory.

Silver is found more or leſs in all parts of the world that are remarkable for metallic veins; moſt plentifully, however, in South America, particularly Peru and Potoſi.

It is found either,

1*mo*, In its metallic ſtate, and pure, or nearly pure.

2*do*, In the form of ores, in which it is the moſt abundant metal, and which are called *proper ores of ſilver:* Or,

3*tio*, As an ingredient, contained in ſmall quantity, in the ores of other metals, which are often, on account of the value of the ſilver, called *ſilver ores;* but diſtinguiſhed by the title of *improper ores of ſilver.*

When it is in its metallic ſtate, it is found formed into fibres, or plates, or branched maſſes, often cryſtallized into regular figures in the cavities of the vein, or intermixed with the ſolid matrix. Not unfre-

quently it adheres to an ore of ſilver. The fineneſs of the fibres is often ſurpriſing. They affect a ſingular arrangement, nearly rectangular, forming chequers that are interrupted like a fret-work ornament in architecture, each being a ſort of quadrangular ſpiral. The geologiſts aſcribe this formation to a gradual ſhrinking of the matrix from without, like what is more diſtinctly obſerved in the round balls of iron pyrites.

Of the ores of ſilver, the proper are chiefly three or four in number:

1. *Minera argenti vitrea*—glaſſy ore.
2. *Minera cornea*—horny ore.
3. *Minera rubra*—the red ore.
4. *Minera alba*—the white ore.

The firſt is very improperly called *vitrea*. It has neither tranſparency nor any other quality by which it reſembles glaſs. It is ſilver combined with ſulphur, and is exactly ſimilar to an artificial compound of ſilver and ſulphur, being ſoft and malleable, almoſt like lead, and of the ſame colour with metallic lead, and very fuſible. The clean pieces of it contain more than three-fourths of their weight of ſilver.

The horny ore has been analyſed with great accuracy by Mr. Woulfe. (*Phil. Tranſ. anno* 1776.) He found it to be ſilver combined partly with muriatic, partly with ſulphuric acid, and there is often pure metallic ſilver, or ſulphurated ſilver, intermixed with it, which darkens its colour. It is a rare ſort of ore, but when ſpecimens of it are found pure and unmixed, it bears a great reſemblance in appearance and properties to muriat of ſilver. It then contains about two-thirds of its weight of ſilver.

The red ſilver ore is of a deep red colour, and more or leſs tranſparent, often cryſtallized, brittle, and very fuſible. Profeſſor Bergmann found that 100 parts of it contain 60 of ſilver, 27 of arſenic, and 13 of ſulphur. But the proportions are a little different in different

ſpecimens; and ſome kinds of it are ſaid to contain antimony inſtead of arſenic.

The white ſilver ore,—*minera alba*, has the metallic opacity and reflecting ſurface when broken, and a white or whitiſh colour, often inclining to yellow or gray. It contains the ſilver combined with arſenic and with other metals, as iron, copper, &c.; and the proportion of the ſilver in it is very various; ſome kinds of this ore being very rich, and others but poor. And it is ſubdivided by mineralogiſts into a variety of ſpecies. Theſe and the improper or poorer ores of ſilver are accurately enumerated and deſcribed in Mr. Kirwan's *Mineralogy*, and others, to whom I refer you,—and I proceed to give a ſhort account of the proceſſes by which ſilver is extracted from its ores.

When the ſilver is found in its metallic ſtate, almoſt pure, and only entangled in the ſtate of filaments, or thin plates, or grains, or branched forms, in a ſtony matrix, there is only one way of extracting it, and that is, by reducing the whole to powder, or ſmall grains, by ſtamping mills, or by other machinery, and macerating and working this powder in tubs with water and quickſilver, ſo as to give it the conſiſtency of mortar for building. It is kept in this ſtate for ſome time,—and is the better of being kept in a warm place; after which, it is diluted with plenty of water in large wooden veſſels; and a circular motion is given to this water by machinery, while more water is ſupplied by a ſmall pipe. Thus the water runs out ſlowly, over the brims of the veſſels, and carries away with it the earthy and ſtony part of the powder. The ſilver and quickſilver united together, and forming a very heavy compound or amalgama, remain at the bottom of the veſſels, and are at laſt completely freed from the earthy and ſtony matter. The amalgama, which is in ſome meaſure fluid, is then taken out and dried, and being tied up in pieces of leather, is ſtrongly compreſſed, that the fluid parts of the quickſilver may paſs through the pores of the leather. Theſe fluid parts of the quickſilver contain a

little only of the ſilver diſſolved in them, and are employed again with freſh ore. The reſt of the quickſilver remains in the leather bags, combined with ſo much ſilver that it has the conſiſtency of a ſtiff paſte, or is almoſt ſolid. This rich amalgam is afterwards expoſed to a proper heat to make the quickſilver evaporate, and leave the ſilver in a pure ſtate; this operation being ſo conducted that the vapours of the quickſilver are condenſed by themſelves in another part of the apparatus.

It often happens that the metallic ſilver is intermixed in the matrix with ſome of the proper ores of ſilver, and alſo with ores of other metals which contain a ſmall quantity, more or leſs, of mineralized ſilver. When this is the caſe, the whole, after it is reduced to powder, muſt be ſubjected to a proceſs of uſtulation, by which the ſulphur and arſenic are evaporated from thoſe parts of the ſilver which are in the ſtate of ore; and the other coarſer metals are oxydated, and therefore ſeparated from the ſilver, which cannot be oxydated or calcined by a roaſting proceſs, but retains its metallic form, and is ready to unite with the quickſilver, in the proceſs of amalgamation. To facilitate this, ſome common ſalt is generally added. It helps to clean the ſurface of the particles of ſilver, and thereby promotes the union of this metal with the quickſilver.

All this is detailed by different authors, who have given treatiſes on this particular ſubject, or who have deſcribed the rich mines of South America, in which the ſilver is almoſt univerſally found in its metallic ſtate. The moſt noted of theſe authors are Alonzo Barba, Don George Juan de Ulloa; but above all Baron Born, who never viſited America, but who, in conſequence of an office he held, was induced to ſtudy the proceſs of amalgamation, as practiſed in Hungary, for extracting ſilver and gold from their matrices. He publiſhed a book on this ſubject, in which he has propoſed ſome important improvements, and deſcribed the whole of his apparatus, and illuſ-

trated his deſcriptions with accurate figures. It is tranſlated into our language by the late Mr. Raſpe.

When ſilver is found in the ſtate of rich ores, in which it is combined with ſulphur or arſenic, and with other metals, the extraction of it is commonly effected by the action of lead, and on a large cupel. This cupel is made of bone aſhes, or often of wood aſhes, from which all the ſalts have been carefully extracted. It is two and a half feet or three feet in diameter, and is formed and fixed in an iron hoop of proper depth, which limits and ſupports the ſides of it, while ſome croſs bars ſupport the bottom. This large cupel in its iron frame is placed in a reverberatory furnace fitted to it, to be heated with flaming fuel; and the iron hoop is defended from the deſtructive action of the heat by covering it well with plenty of bone aſhes, made to cohere with a little water. The flame and heat are applied to the cavity of the cupel only; the under ſurface is defended from the heat. A good quantity of lead is then melted, and made red hot on this cupel; and the ſilver ore is added to the lead. A part of the lead immediately unites with the ſulphur and arſenic, or other matters with which the ſilver was combined. And theſe matters occaſion or promote the ſcorification of a part of the lead, which is alſo promoted by the wind of one or two bellows which play on the ſurface of the metal. The ſcorified lead is a powerful flux or diſſolvent for the earthy and ſtony ſubſtances, or other metals in which the ſilver was involved; and the whole becomes fluid ſcorified matter, flowing uppermoſt, or around the melted and red hot metallic lead. This laſt powerfully abſorbs the ſilver that has been extricated from the ore. The ſcoriæ thus produced are ſoon after drawn off by making a little gutter in the edge of the cupel, on the oppoſite ſide, from the blaſt of the bellows. And the lead, if ſufficiently enriched, is further ſcorified by heat and air, until it be totally changed into litharge, the ſilver remaining at laſt on the cupel. In ſcorifying lead, to extract ſilver from it in the large way of working, the ſcorified lead is not allowed to ſink into

the cupel, or to be abſorbed by it, as is done in refining ſmall quantities of ſilver, or in aſſays. This at leaſt is avoided as much as poſſible. The melted litharge is made to run out of the cupel by the little gutter I mentioned, and it drops into a cavity below, where it immediately congeals. The reaſon of this is, that when the litharge is pure, it is very eaſily reduced again into lead. But when it is abſorbed into the bone aſhes, it is difficult to reduce it; and it cannot be reduced without conſiderable loſs.

Theſe proceſſes are ſometimes varied in other ways, the reaſons of which you will eaſily underſtand from what has been already explained to you. If an ore, for example, containing ſome ſilver, is very much brangled or diſperſed through a large quantity of ſtony matter, the whole is melted among the charcoal; ſome other kind of ſparry or ſtony matter being added to promote the fuſion of that which involves the ore; and they add alſo ſome litharge or ſcorified lead which has been produced in other proceſſes, ſuch as the cupellation laſt deſcribed.

GENUS XIV.—GOLD.

This metal has been diſtinguiſhed by the chemiſts with the titles of *ſol* and *rex metallorum*, on account of its excelling all the reſt by the perfection of its metallic qualities; but chiefly, I imagine, becauſe it is the moſt highly prized in ſociety.

When pure, it is ſoft and flexible, not elaſtic or ſonorous. I already noticed its great ductility and malleability. Mr. Lewis conſiders its ſpecific gravity with great accuracy. It is about nineteen times as heavy as water; and a cubic inch of it weighs 4902 grains, or 10 ounces and 102 grains. It requires for its fuſion a very ſtrong red heat, or almoſt a white heat, a heat ſtronger than that of melting ſilver; and when in fuſion, it emits or reflects a bluiſh green light from its ſurface.

Its ſurface always remains bright in the fire; and if foul or tarniſhed before, it is always cleaned and brightened by a red heat.

When we try it in mixture with ſalts, we find that none of the acids, applied in their ordinary ſtate, produce any effect on it. The ſulphuric acid, or the nitric, or the common muriatic, if applied ſeparately, either in their watery form, or in the much more active ſtate of dry and burning hot vapour in cementation, make no impreſſion on it, or ſhew any power to diſſolve it in its pure and metallic ſtate. Upon this is founded a trick for defrauding the purchaſers of gold. The bars or ingots of impure gold are cemented for a while with proper materials, which refine it to a depth proportioned to the continuance of the cementation. Trinkets treated in this manner bear to be burniſhed and poliſhed; and when tried by the touchſtone appear perfectly fine. When trinket gold appears of this extreme fineneſs by the touchſtone, it is always to be ſuſpected as being only a cruſt covering baſe gold. An ingot, ſo treated, appears fine, even when cut through with a chizel, becauſe this carries a film along with it from the ſurface, which covers the reſt. It is proper, therefore, to cut it only half through, and then to break it.

The ſaline ſolvents which act on metallic gold, are only the oxygenated muriatic acid, and the nitro-muriatic ſolvent, which is therefore called *aqua regia*. The oxygenated muriatic acid is effectual in conſequence of its power to oxydate the gold, which the common muriatic acid cannot do: And the nitro-muriatic acid has the ſame power.

This mixed acid may be prepared and applied by different ways, ſo as to be effectual in diſſolving gold; as

1*ſt*, By mixing the pure nitric and muriatic acids together.

2*dly*, By adding common ſalt, or ſal ammoniac, in moderate quantity, to the nitric acid, and diſtilling this mixture.

3*dly*, The mixture I juſt now mentioned can be employed very well without diſtilling it.

4*thly*, Alum, nitre, and common ſalt boiled with water, form a ſolvent of gold, though not a ſtrong one.

Scheele, the firſt diſcoverer of the oxygenated muriatic acid, was of opinion, that the nitric acid dephlogiſticated, or, in other words, oxygenated the muriatic, and thus enabled it to diſſolve the gold.

But Dr. Prieſtley found that *nitroſe* acid, and eſpecially the moſt red and volatile vapour of it, which he calls nitrous vapour, when added to the muriatic acid, occaſions a more rapid diſſolution of the gold than the more perfect nitric acid does, which cannot eaſily be explained upon Scheele's principle.

Another fact, analogous to this obſervation of Dr. Prieſtley's, is, that when the ſolution in aqua regia is going on in a ſlow and languid manner, the addition of a ſmall quantity of æther, or of alcohol, makes the ſolvent very active. The ſolution goes on briſkly, and is accompanied by much effervеſcence. This alſo ſeems very unlikely to produce an oxygenation of the muriatic acid. It ſeems more fitted for depriving it of oxygen; and it is not clear how the vapours of nitroſe acid ſhould ſupply oxygen more readily than nitric acid, which contains more of it. Yet, from what experience I have in the diſſolving of gold, and by attending to the odour of the acid when it is acting properly, I am perſuaded that Scheele was right. While the acid is acting on the gold, it always gives the diſtinguiſhing pungent diſagreeable odour of the oxygenated muriatic acid. When it is ſaturated, the nitroſe fumes are plainly diſtinguiſhable, and then the addition of a little muriatic acid immediately renews the action, and yields the ſmell of the oxygenated muriatic acid. The addition of a little nitric acid, when the ſolution flags, does not produce the ſame effect. From this I think the inference is plain. The muriatic acid is the baſis of the ſolvent, but requires more oxygen, and the ſaturated ſolution is a ſolution in oxygenated acid. Therefore more nitric acid can do nothing. More muriatic acid can, becauſe there is enough of nitric in the mixture to oxygenate it.

But there is alſo reaſon to be of opinion that the acid of nitre itſelf, when it has loſt a part of its oxygen, becomes in ſome meaſure a ſol-

vent of gold, or aſſiſts in diſſolving it, and that in the nitro-muriatic ſolvent, both acids act.

It has been found by experiment, particularly by Dr. Brandt, that a ſtrong nitroſe acid, although employed alone, will diſſolve a ſmall proportion of gold, when boiled with it ſome time. But, in truth, it is only a very ſmall quantity that is thus diſſolved; and even this ſmall quantity is liable to ſeparate again from the acid ſpontaneouſly. Moreover, when gold is diſſolved in the uſual manner in aqua regia, the muriatic acid adheres the moſt ſtrongly to the gold, and is the principal ſolvent. Nitrous vapours ariſe from the ſalt while evaporating to dryneſs. Mr. Lewis remarks, in his Notes on Neuman, that when the ſolution of gold is diſtilled, the nitrous acid eaſily paſſes over into the receiver, leaving the muriatic alone in poſſeſſion of the metal. And when gold is obtained in the ſtate of an oxyd, by precipitation from its ſolution, or any other proceſs, the muriatic acid alone, and even a weak one, can eaſily diſſolve it, and forms a ſolution which has all the properties of the common ſolution of gold.

It is a ſufficient anſwer to any doubts about the real ſolvent of gold, that the compound reſulting from the ſolution in the oxygenated muriatic acid is perfectly the ſame in all reſpects with the ſalt formed by any of the compounded ſolvents. The nitric, or even nitrous acid may perhaps oxydate the gold, but it does not combine with it in a ſaline form.

The ſolution of gold is always of a rich yellow colour: But when applied to animal or vegetable ſubſtances, it produces an indelible ſtain, of a reddiſh purple. By evaporation, it can be made to form yellow cryſtals. In theſe the muriatic acid adheres ſo ſtrongly to the gold, that it cannot be completely ſeparated by heat. When they are expoſed to heat in a retort, part of the gold riſes with the acid, and is condenſed into a red or deep yellow fluid, or into cryſtals or flowers of the ſame rich hue, in the neck of the retort, called by the alchemiſts the *red lion*.

We can eaſily, however, precipitate the metal from its ſolvent by various additions, ſuch as alkaline ſalts and other metals.

Fixed alkalis and lime precipitate gold of a ruddy yellow, and the oxyd is ſoluble in all the acids.

Nut galls, or the gallic acid, alſo precipitate gold of a purple colour; and it was diſcovered by Mr. Monnet, that this precipitate diſſolves moſt readily in nitric acid, giving it a fine blue colour.

The volatile alkali is one of the beſt precipitants of the gold, and produces the remarkable precipitate named *aurum fulminans*. It is an oxyd of the gold, which has a dull yellow colour, and is thus named on account of its diſpoſition to explode with aſtoniſhing violence, when expoſed to a very moderate degree of heat.

To ſee this exploſion properly in its full energy, we muſt waſh away the ſaline matter from the precipitate carefully with pure water, and then dry it well in a cool place. After this preparation, if we expoſe it to a gradual heat, it firſt becomes dark coloured, and ſoon after, if the heat be increaſed, it explodes with an obſcure and momentary flaſh, viſible in darkneſs. And when the experiment is made with a view to know what becomes of the gold, by covering it, for example, with a glaſs bell, it is found diſperſed in ſmall particles, and all of it reſtored to its metallic form.

The exploſion of this preparation of gold is ſo exceedingly violent, that great caution is required to prepare it with ſafety, or to make experiments with it; terrible conſequences having in ſome caſes proceeded from the want of care or ſkill in handling it. Its force is ſuch, that when ſo ſmall a quantity as ten grains are exploded on a thin metallic plate, it makes an impreſſion like that of the ſtroke of a hammer, or ſometimes breaks a hole through it. And after it is rightly prepared, it is dangerous to treat it in any manner by which it may be heated, or expoſed to friction or compreſſion. Grinding it in a mortar, nay even the friction of the glaſs ſtopper on a grain left in the neck of the phial in which it is kept, has been known to occaſion its exploſion.

It is remarkable that the heat produced in this explosion is very small. It will not singe paper. If a little be rubbed into a bit of soft spongy paper, and held over a candle, or before a hot fire, it will turn dark coloured, and then go off in a succession of cracks, with scarcely any light, and without changing the colour of the paper. I imagine that even the light arises from an electrical concussion of the air. *(See Note* 31. *at the end of the Volume.)*

The nature of this surprising preparation of gold, and the cause of its explosion, has been but lately even guessed at with any probability, for I cannot say that it has been discovered: And the sagacious conjecture was made by Mr. Scheele. Formerly it was supposed to contain nitrous salts, combined with the gold, and that these gave it this fulminating quality. And it is in fact a little heavier (almost one-fourth) than the gold from which it is prepared. But neither can any nitrous salts be found in it, nor is the heat at which it explodes sufficient for the explosion of nitrous compositions.

When I was engaged in making my experiments on magnesia and other alkaline substances, I had a notion that the explosion of aurum fulminans depended on carbonic acid communicated to the gold by the precipitating alkali;—and this conjecture was founded on my observing that gunpowder and pulvis fulminans contained, or produced in the explosion, a great quantity of this gas. But the important discoveries which have been made since that time shew clearly that it proceeds from a very different cause.

Professor Bergmann, in a dissertation on aurum fulminans, proves that it cannot be made without volatile alkali. If the gold be dissolved in a solvent composed of the pure nitric and muriatic acids, and we then precipitate it with a fixed alkali, we get an oxyd totally destitute of the exploding power; but if we digest this oxyd with liquid volatile alkali, we then give it that property. And further, the pure or caustic volatile alkali serves rather better for making good aurum fulminans than the carbonat of ammonia. All this, and many

other facts to the ſame purpoſe, were aſcertained by Profeſſor Bergmann.

And afterwards Scheele in Sweden, and Berthollet in France, gave us more complete knowledge on this ſubject, by demonſtrating the preſence of volatile alkali adhering to the gold in this preparation, and ſhewing by experiments, that this volatile alkali is decompounded when the exploſion takes place. Mr. Berthollet, equally judicious in his choice of deciſive experiments, and ingenious in his concluſions from them, made two experiments on theſe compounds, which leave little doubt as to their chemical conſtitution. He expoſed aurum fulminans in a copper tube to a very gentle heat, gradually increaſed, and obtained from it great abundance of alkaline gas, by which its weight was diminiſhed conſiderably, and its exploding power entirely taken away. He exploded dry aurum fulminans in a proper apparatus, and obtained water and azotic gas,—and the gold was reduced to the metallic ſtate.

The volatile alkali is now known to be a compound of hydrogen and azote. The precipitate of gold alſo contains the oxygen which the metal received from the nitric acid. The attraction, however, of the oxygen for the metal, and of the hydrogen for the azote, prevents them from acting on each other until heat be applied; but when heat is applied, the oxygen and hydrogen unite with a rapid or momentary combuſtion, and form vapour of water with an exploſion; and the azote alſo aſſuming the elaſtic aëreal form, the exploſion is thereby increaſed *.

Another diſcovery which has been lately made, and which is connected with the ſubject, is, that ſilver can alſo be prepared ſo as to have the properties of fulminating gold, and that in a far higher degree than the gold itſelf. This diſcovery was alſo made by Mr. Berthollet, and has been conſidered already.

* I obſerve that ſome French and Italian chemiſts conſider this phenomenon as the combuſtion of azote; but this is inconſiſtent with the experiments of Mr. Berthollet.

EDITOR.

As to the formation of this curious compound I muſt obſerve, that when the gold is precipitated in this manner from the aqua regia by alkaline ſalts, it may be rediſſolved, like the precipitates of ſome other metals, by adding to the mixture a ſuperfluous quantity of the alkali. The fixed alkalis diſſolve it better than the volatile alkali; and, according to Margraaf, the phlogiſticated alkali is better for this purpoſe than the common or pure fixed alkali. Theſe ſolutions are not permanent, the gold being depoſited from them, eſpecially from the volatile alkali.

If we chooſe to deprive the precipitate of its exploding power, and bring back the gold to its metallic ſtate, we can effect this by ſeveral different methods; as,

1*ſt*, By calcining long, with a very gentle heat, inferior to that which makes it explode. Thus it ſlowly aſſumes a dark purple colour; and the volatile alkali is thus evaporated from it. This method requires great caution to avoid friction or concuſſion.

2*dly*, By heating it in a ſtrong and cloſe veſſel *.

3*dly*, If the particles of it be ſeparated from one another by the interpoſition of any powdery ſubſtance mixed with it on purpoſe, as ſulphur, or any of the neutral ſalts, or earthy powders, it may be heated ſecurely, until it is deprived of the power of exploding, and can afterwards be melted into a maſs.

4*thly*, If ſome ſtrong ſulphuric acid be boiled with it, and evaporated from it, the gold remains bereft of its exploding power.

5*thly*, The vitriolic æther, by digeſtion, ſimply reduces a part, and diſſolves a part, which is alſo afterwards reduced.

* A ſmall quantity of aurum fulminans was ſhut up in an iron ball, of which it completely filled the cavity. This was expoſed to a great heat, but did not explode. (*See Fourcroy*, vol. iii. p. 369. *Edin.* 1788). Can this have happened becauſe external preſſure prevented the chemical combination, as we ſee it prevent the abſorption of caloric by water, ſo as to make it boil?

EDITOR.

6thly, Muriatic acid, digeſted with it, diſſolves it; and then, by precipitating with the fixed alkali, we obtain it no longer fulminating.

You will find it alleged in books, that waſhing aurum fulminans with much water, or boiling it in water, took away its exploding power; but this is a miſtake. The more perfectly it is waſhed, it explodes the better: And if we neglect to waſh it, and thus leave in it any quantity of the ſalts formed in precipitating it, it will not explode well.

Such are the effects of alkaline ſalts on the ſolution of gold.

This metal can alſo be precipitated in ſome meaſure from its ſolution, by ſome inflammable fluids, as ſome aromatic oils, and ſpirit of wine. Theſe liquors act by attraction for the acid.

The effects of the vitriolic æther have been thought more remarkable. It ſeizes on the gold immediately, and often reduces it to the metallic ſtate, in fine films, which are rendered buoyant, even in the æther, by the adheſion of imperceptible bubbles of vital air. By adding æther to a ſolution of gold in aqua regia, the whole of the metal may be brought to the ſurface, forming a ſtratum a-top of the æther; and neither of the fluids below (the æther nor the aqua regia) contain a particle of it. Generally, however, the gold remains for ſome time diſſolved in the æther (but completely abſtracted from the acid), tinging it of a rich yellow.

This effect of the æther has been the more admired, on account of its being the lighteſt fluid of any we know, and therefore was thought the leſs qualified to ſuſpend ſuch a ponderous metal. But the power of chemical attraction performs greater wonders than this; for gold can be even rendered volatile by ſome of the ſalts which have the ſtrongeſt attraction for it. And in this caſe of the diſſolution and ſuſpenſion by æther, the æther acts more by its attraction for the acid with which the gold is united, than for the calcined gold: But it appears alſo to have ſome attraction for the oxydated gold itſelf. Mr. Lewis and

others ſay that aurum fulminans can be diſſolved by it at leaſt in part. Still, however, I am inclined to ſuppoſe that the æther acts, even in this caſe, by its attraction for the oxygenous principle, and the ſmall quantity of ſaline matter combined with the gold; for it is certain that when we apply it to pure gold in its metallic ſtate, it has not the leaſt power to act on it, or to diſſolve it. And when it diſſolves the aurum fulminans, it does not hold it long ſuſpended, but depoſits it in its pure and metallic form *.

Other metals alſo can be employed to precipitate the gold, and there are ſeveral that precipitate it, although they are themſelves combined with an acid. They produce this effect in conſequence of the ſtrong elective attraction which they have for the muriatic acid, and for the oxygen, both of which they ſeparate from the gold.

The metallic ſolutions which have been applied to this purpoſe, are,

The ſolution of ſulphat of iron.

The ſolution of nitrate of quickſilver;—and

The ſolution of tin in the nitro-muriatic ſolvent.

It is eaſy to underſtand how the two firſt produce their effect.

* Since we ſee the æther ſeparate the gold from its ſolvent in the metallic ſtate, we can ſcarcely expect any action of æther on metallic gold. Experiments on this metal being ſo expenſive, they have not been made on large enough quantities for obſerving with accuracy what changes are induced on the æther, in this experiment. The phenomena accompanying the ſeparation of gold by aromatic oils, give conſiderable information, and very conformable to Dr. Black's opinion. Theſe oils are inſpiſſated in the ſame manner as by the contact of vital air. We ſhould expect a ſimilar change on the æther to what pure vital air produces on it, foraſmuch as it deoxydates the gold; and we ſhould expect ſome combination of the æther with the acid. If we obſerve the æther changed as it would be by ſo much aqua regia, we ſhould aſcribe the ſeparation of the gold entirely to the attraction of the æther for the acid. If the change be different, we ſhould aſcribe it, at leaſt in part, to its attraction for pure oxygen. The phenomena give indications of both. The æther mixes with the acid only to a certain degree, and the acid, thus combined with æther, has no further action on metallic gold.

EDITOR.

And I ſhall only obſerve, that the precipitate by the mercurial nitrate is very readily diſſolved by mercury. It is uſeful in this way for gilding upon glaſs or porcelain. But the precipitate by martial vitriol is far preferable, affording a much richer colour, ſeemingly owing to a ſmall quantity of copper contained in the vitriol.

The effect of the ſolution of tin depends on this particular circumſtance, that though the tin be already combined with a quantity of the muriatic acid in the nitro-muriatic ſolvent, and alſo with a quantity of oxygen, it is not ſaturated with either of them. It has ſtill an attraction for more, and therefore takes them from the gold.

The precipitate of gold, thus obtained, is the moſt remarkable of any by its fine and rich colour. The colour is ſo deep, that this experiment is a way to diſcover the ſmalleſt quantity of gold in a ſolution. And a red or purple appears to be the colour natural to gold, when very ſubtilely divided,—by electrical fire, for example, or other means. The purple ſtain given by the ſolution of gold to animal and vegetable ſubſtances, is another example.

This precipitate is valued, and very much uſed, as a fine purple for enamel colours. It has the advantage of enduring the fire without undergoing any change of its colour, to which many other enamel colours are liable.

I have already deſcribed the proceſs for preparing the ſolution of tin that is employed in the preparation of this purple precipitate of gold, known by the name of the *purple of Caſſius*. It was deſcribed as a ſolution of tin in aqua regia, and with every precaution to have the metal as ſlightly calcined as poſſible, and the acid completely ſaturated with tin. I muſt now take notice of the circumſtances which muſt be attended to, in order to have the ſolution of gold in the moſt proper ſtate. It is found often to fail, when the gold is diſſolved in a mixture of the two acids; ſeldom, when the aqua regia is made by adding common ſalt, very pure, to nitric acid; and ſcarcely ever, if ſal

ammoniac be employed. The greateſt nicety lies in the degree of dilution of the ſolution of tin. As this depends on the oxydation of the tin, it is beſt to determine it by trial. Having diluted the tin ſolution with eighty times its bulk of water, put three or four portions of it into glaſſes, and dilute each of them differently; then, dipping a glaſs rod to a certain depth in the ſolution of gold, rinſe it in one of the glaſſes; do the ſame to another; to a third, &c.; then notice in which glaſs the precipitate has the richeſt and moſt beautiful tint of purple, and dilute the whole according to that ſtandard. The precipitate both forms and falls down very ſlowly, being in ſome degree gelatinous; by long reſt, however, it all falls down, and then the clear liquor may be decanted off, and the precipitate cleared by edulcoration and a filtre.

Orſchall, one of the celebrated older chemiſts, ſays that he obtained a very fine precipitate by means of the fuming liquor of Libavius; alſo by means of a ſolution of tin with corroſive ſublimate made by deliqueſcence; and a ſtill more beautiful precipitate than what tin can produce, by means of mercury diſſolved in aqua regia.

But Orſchall knew only the preparation of the enamel colour, which has great body, as the painters call it, but little tranſparency. The tranſparent red and purple is of great value for *ſtaining* glaſs. It is made by diluting the purple of Caſſius with pure cryſtal or glaſs. This is a preparation ſtill more capricious and uncertain. Frequently the glaſs has no colour whatever; but if a rod of ſuch glaſs be made red hot, and held in a ſmoky flame of wood, it becomes purple in an inſtant. But this is merely ſuperficial; and if the glaſs is to be formed into any other ſhape, the colour vaniſhes in the working, and it again requires the aſſiſtance of the oily flame. This is called *Jew's glaſs*.

Neuman ſays, and Dr. Lewis confirms it in his Notes, that the preparation of the purple precipitate never fails, if made by ſimply putting pure tin into the ſolution of gold greatly diluted.

Margraaf has publiſhed, in the Mem. Acad. Berlin, 1779, a ſeries of moſt judicious experiments for determining the beſt proceſs for this valuable precipitate; and I refer you to him for farther information. I muſt obſerve, however, that our artiſts call the purple of Caſſius a tender colour, becauſe a conſiderable heat makes it tranſparent, and therefore of a different tint, according to its thickneſs on the ware. It does not ſuit enamel, therefore, ſo well as ſtaining of glaſs, becauſe the other colours by copper, cobalt, &c. require much higher heats in order to bring them to their full colour, and are therefore melted ſeveral times in crucibles before they are ground to powder for the painting in enamel. Even then, they require more heat than the purple of Caſſius bears without riſk of loſing its body.

Inflammable Subſtances with Gold.

Sulphur, which unites ſo readily with moſt of the other metals, cannot be combined with gold. But if we firſt join the ſulphur with a fixed alkali equal in quantity to the ſulphur, the ſulphuret thus formed, if applied to gold in thin plates or leaves, and in the way of fuſion, very readily combines with it, or diſſolves it; and if the compound be immediately poured out of the crucible, and ſoon after diſſolved in water, a part of the gold will be diſſolved along with the ſulphuret, while the reſt remains in the ſtate of a very ſubtile powder. Dr. Stahl had a notion that this proceſs, which is certainly an ancient one, was known to Moſes, and was practiſed by him when he made the children of Iſrael drink the golden calf. It is indeed true that this potion is extremely nauſeous, having a pungent bitterneſs not to be felt in the ſimilar preparations of other metals.

The effects of alcohol, æther, and aromatic oils, on the ſolution of gold have been mentioned already.

The only other inflammable ſubſtance remarkable for its effects on gold, is phoſphorus, the powers of which, with reſpect to metals in general, have been ably inveſtigated by M. Pelletier. When thrown

into melted gold, a certain quantity unites with the metal, forming a phoſphoret of gold, which is more fuſible than the gold by itſelf. But if the compound remain in the fire, and air be admitted, the phoſphorus is gradually burnt, and changed into acid, which ſeparates from the gold.

Relation of Gold to other Metals.

Gold may be mixed with any of the other metals; and it is by the admixture of ſome of theſe that it is made to appear of thoſe different colours which are ſeen in the inlaid gold of trinkets and toys. Copper inclines the colour of gold to red; ſilver makes it pale; and if the ſilver be one to four of the gold, a greeniſh hue is produced. Pure gold is a full yellow. The Venetian chequin has the richeſt colour of any gold; and the art of giving it this high colour is kept a ſecret in the mint of Venice. I made a piece of fine gold acquire the ſame colour, (but it was only ſuperficial) by keeping it long red hot under charcoal duſt.

In its pure ſtate, it is thought too ſoft and flexible for making toys and utenſils, or coin. And the general practice is to add ſome of the other metals, which give it more ſtiffneſs and hardneſs. This addition is named the *alloy* of the gold. It is commonly ſilver and copper, of which one part is added to eleven of the pure gold, for the ſtandard of theſe kingdoms. One pound avoirdupoiſe of ſtandard gold, is worth $56\frac{1}{1}\frac{1}{2}\frac{2}{3}$l. Sterling.—1000l. Sterling weighs (avoirdup.) 7 pound $9\frac{1}{1}\frac{4}{0}\frac{3}{0}\frac{}{0}$ ounces.

In ſpeaking of the quantity of alloy in gold, the term carat has been uſed. A carat is the twenty-fourth part of a maſs of gold, great or ſmall: And each carat is ſubdivided into twenty-four parts, denominated grains. Our coin then is of twenty-two carats.

The relation of gold to quickſilver, and the art of gilding metals founded on it, has been noticed already in treating of quickſilver.

Other methods are practiſed for gilding, in which mercury has no

ſhare. As almoſt all the metals precipitate gold from its ſolution, and precipitate it in the metallic ſtate, any of theſe metals, put into a ſolution of gold, will be immediately covered with the depoſited gold. This covering will rarely be made to adhere, becauſe the ſurface of metal which we would gild is oxydated. But, by methods reſembling what I deſcribed for whitening or tinning pins, the pure metals may be applied to each other, and then the burniſher makes them adhere, ſpreading, at the ſame time, the gold over the parts where none was depoſited. The beſt of theſe proceſſes are kept ſecret by the poſſeſſors. There is a family at Nuremberg, which has preſerved one a ſecret for upwards of two centuries; and their gilding, even on the moſt common work, has a ſolidity and richneſs of colour that is not equalled by any other artiſts in Europe.

There is ſtill a more ſimple way of ſlight gilding. Linen rags, ſoaked in the ſolution of gold, are burned to aſhes;—a ſmooth cork, ſuperficially charred, is wetted and dipped among theſe aſhes, and then rubbed carefully over the piece to be gilded. The reduced gold among the aſhes is thus preſſed on the work ſo as to adhere; and by going over it ſeveral times, it is completely covered; and bears to be rubbed very hard with a fine linen rag, ſtrained on a bit of cork. This gives the work a fine poliſh, and great brilliancy; and is pretty durable on the inſide of cups, and other ſituations which do not require often ſcouring.

You muſt have often heard the terms of *tried gold*, and of the *trials of gold*. Theſe are trials, or proceſſes, by which we can aſſure ourſelves whether a metal which reſembles gold be gold or not; and if it be gold, whether it is pure or alloyed; and if alloyed, what proportions of pure gold and of alloy it contains. The operations which have been long in common uſe for theſe purpoſes are five in number:

1. The uſe of the touchſtone, *(lapis lydius)*.
2. Cementation.
3. Refinement with antimony.

4. Cupellation with lead.

5. Parting, or the depart.

1*ſt*, The touchſtone ſhews whether a metal be gold or not; and if gold, of what fineneſs nearly, by needles. The piece of gold is rubbed on a black ſtone of the jaſper kind, having a fine ſiliceous grain and argillaceous cement. Some of the hardeſt of the antique, or of Wedgewood's black pottery, anſwers the ſame purpoſe. The metal leaves a trace on the ſtone. A ſet of touch needles are made, conſiſting of gold, with various proportions of alloy. The tryer makes a ſtroke with one of the needles cloſe by the one made by the metal under trial, and changes the needle, till he has got a ſtroke exactly like it: Thus he judges of the proportion. To be more exact, he draws over both ſtrokes a pencil dipped in aqua regia. This diſſolves all the gold, and leaves the ſilver. The proportion of alloy is thus more clearly ſeen.

This method will not detect adulteration, when the piece has been cemented in the manufacturing. This makes it fine ſuperficially, though internally baſe. If the ſtroke ſhew very fine gold, we may be almoſt certain that the piece has been cemented.

2*d*, Cementation is ſeldom uſed, as requiring repetitions. Although a ſmall quantity of baſe metal, concealed in a large quantity of gold, is thereby ſhielded from the acids acting in the humid way, they cannot reſiſt their action in dry burning vapours. Therefore adulterated gold, being firſt laminated, is ſtratified with a mixture of calcined martial vitriol and nitre, or common ſalt, (not both), and a quantity of powdered brick, and expoſed to a cementing heat for ſome hours; the piece is taken out, melted, and again laminated, and again cemented,—" ſeven times tried in the furnace." By each operation part of the baſe metal is deſtroyed.

3*d*, Crude antimony is more frequently uſed. It is better than pure ſulphur, becauſe pure ſulphur is too volatile, and metallic antimony waſhes down the gold; but the crude antimony abſorbs and ſcorifies all the baſer metals.

4th, Cupellation is ſtill more frequent as a means of purging the gold of copper, and all baſer metals; and an addition of ſilver facilitates this operation, and makes it more perfect. If there be no ſilver in the mixed metal, the gold retains, in the end of the cupellation, a ſmall portion of copper, which it defends from the action of the lead and heat.

5th, But after thus cupelling the gold with this admixture of ſilver, we muſt have recourſe to the operation of parting, to have the gold pure. This parting is the ſeparation of the gold from the ſilver, performed by aquafortis, or aqua regia. Aquafortis is commonly employed, and the uſe of it is quite ſimple and eaſy. I ſhewed you an example when I diſſolved ſilver in aquafortis. The ſmall portion of gold which the ſilver contained remains undiſſolved, and retains its ſhape, and it needs only to be boiled with a little freſh aquafortis to make it quite pure; for if this be not done, it retains ſome of the ſilver. In order to enable the aquafortis to act properly on this metallic mixture, there muſt be at leaſt twice as much of the ſilver as of the gold, and the aquafortis muſt be ſufficiently ſtrong. It is alſo uſual to reduce the metallic maſs into ſmall grains and fragments, by melting it, and pouring it into cold water. This is done to increaſe the ſurface of contact between it and the aquafortis. Or if we have but a ſmall quantity of it, as in aſſaying, it is rolled out into a thin plate, between two ſmall ſteel rollers: And this plate is twiſted into a ſpiral.

When the mixture contains more gold than ſilver, in the proportion of two to one at leaſt, we may uſe aqua regia to ſeparate theſe two metals. It will diſſolve the gold, and leave the ſilver at the bottom, in the form of muriatic ſilver. The ſolution of gold being then carefully ſeparated from the ſilver, the gold is commonly precipitated with ſolution of quickſilver in aquafortis. This occaſions the gold to fall in the form of a dark-coloured powder, which, after it is well waſhed, is eaſily melted into a maſs with a little borax.

There is another method of refining gold, which is now commonly practiſed, when the gold contains a ſmall quantity of alloy only, and that of ſuch a nature as to deprive it of toughneſs and malleability, ſuch as iron, tin, braſs, or any of the ſemi-metals. The method I mean is, to melt it, and add to it repeatedly, while in fuſion, ſmall doſes of the corroſive muriat of quickſilver, until it is fine or tough. This corrodes the alloy, and ſoon brings it to the ſurface as a ſcoria, where it works off.

When a ſmall proportion only of gold is contained in a metallic mixture, the proceſſes for extracting it are often different from thoſe already deſcribed. In general it is ſeparated from all other metals, except copper, in the ſame manner as ſilver is extracted from them. But when the gold is contained in copper, it cannot be extracted by the ſame operation which ſerves for extracting ſilver from copper, which is the addition of lead and the eliquation of the lead. The gold is not brought out by this proceſs: It has a ſtronger attraction for copper than for lead. A ſucceſsful method was, however, diſcovered in Germany, which was very profitable to thoſe who practiſed it firſt; and it ſtill continues to be the beſt method for extracting a little gold from metallic copper. It is done by melting the copper with ſulphur and lead at the ſame time. The copper unites with the ſulphur, and is thereby diſpoſed to quit the gold to the lead. The proceſs is deſcribed in Lewis' *Commercium*, and Cramer's book on *Aſſaying*.

A ſomewhat ſimilar proceſs, by which gold was extricated from ſilver that contained but a ſmall quantity of it, had long been practiſed before the chemiſts thought of employing it in the caſe of copper. Cramer deſcribes this proceſs with ſilver very particularly.

Natural Hiſtory of Gold.

It muſt be acknowledged that gold, though it be not the moſt uſeful of the metals, has ſome admirable qualities. Its rich colour and luſtre, which are never obſcured with tarniſh or ruſt, and its aſtoniſh-

ing extenſibility, which enables us to employ it in the embelliſhment of the works of art at a very moderate expence, are one foundation for the value that is ſet on it. The principal cauſe, however, of the high price of gold, is the difficulty of procuring it. And yet there is more of it produced by nature than is commonly imagined; but it is generally diſperſed through ſuch immenſe quantities of other matter, that it cannot be collected without great labour and expence.

The Spaniſh and Portugueſe parts of America, and ſome parts of India and Africa, afford the largeſt quantities of gold. Amazing reports have been publiſhed of the abundance of this metal in ſome of the Spaniſh poſſeſſions in America; but theſe reports are publiſhed in late accounts of ſome newly diſcovered places where gold has been found, and the accounts of ſuch new diſcoveries are commonly amplified *.

Wherever gold occurs, it is found much more commonly in its metallic ſtate, and nearly pure, than in the ſtate of an ore. This is probably a conſequence of its having no attraction for ſulphur, and very little for arſenic, and of its reſiſting the action of the mineral

* Some parts of the new kingdom of Grenada (which is a high inland country eaſt of the Andes, and in the north end of South America) are rich in gold, which is all waſh-gold. On a riſing ground near Pamplona, ſingle labourers have collected in a day what was equal in value to 1000 peſos, or to 225l. = 57 ounces 4 drachms 42 grains. A late governor of Santa Fe brought with him to Spain a lump of virgin gold eſtimated to be worth 740l. Sterling. (The weight of it muſt have been about 189 ounces, or 23 merks and 5 ounces, even ſuppoſing it gold equal in purity to Engliſh ſtandard.)

At Cineguilla, in the province of Sonora, the Spaniards found a plain fourteen leagues in extent, in which they found waſh-gold at the depth of only ſixteen inches, the grains of ſuch a ſize that ſome of them weighed nine merks, and in ſuch quantities, that in a ſhort time, with a few labourers, they collected 1000 merks of gold in grains, (equal in value to 31,219l. 10s. Sterling) even without taking time to waſh the earth that had been dug, which appeared to be ſo rich, that perſons of ſkill computed that it might yield gold to the value of a million of peſos; which is equal to 225,000l. Sterling. In one place, called the *Mine Yecorata*, in Cinalod, they found a grain of gold 22 carats fine, which weighed 16 merks 4 ounces 4 ochavas. It is now depoſited in the royal cabinet at Madrid. This grain is worth $498\frac{106}{113}$l. Sterling.

acids. I believe all the gold collected in America and Africa is found metallic, and uncombined with the common mineralizing ſubſtances. But in Europe there are ſome mines which yield *ores*, containing a ſmall quantity of it. Theſe ores are not, properly ſpeaking, ores of gold, they are ores of other metals; but the ſmall quantity of gold which they contain along with the other metals, occaſions their being conſidered as ores of gold. In Hungary, a conſiderable quantity is extracted from ſome ores of quickſilver, and from a pyrites of iron and ſulphur. In the Hartz foreſt in Germany, there is an ore which affords zinc, and lead, and ſilver, and a ſmall quantity of gold. And both there and in other parts of Europe, there is found in ſome places a black ſand like ſmall grained gunpowder, which is an ore of iron, and which contains ſome gold.

In ſome of thoſe ores, it is either intimately combined and mineralized with the materials of which the ore is principally compoſed, or, if it be in its metallic and pure ſtate, it is in ſuch minute atoms, that it is not diſcoverable by viſion until it be collected together by itſelf. There is reaſon, however, to believe that it is always in this ſtate. When the Hungarian pyrites is diſſolved with aquafortis, it is ſaid that the gold is left by that acid in the form of minute atoms, and fine films, which are in a metallic ſtate. And as this pyrites varies much in the quantity of gold it contains, and ſome of it does not contain any, there is reaſon to believe that all the gold in it is metallic and pure, and only diſperſed through it in very minute films not mineralized. However that be, by far the greater part of the gold which is collected in different quarters of the world is found free from mineralizing ſubſtances, and nearly pure, or contains only ſome ſilver, and ſometimes a little iron or copper. And this virgin gold, as it is called, is found in two ſtates or conditions, that is, either in the ſolid veins of the mountains in which it ſeems to have been originally formed, or depoſited by nature like other metals, and from which it is in this caſe cut out by mining in the uſual manner,—or

mixed with the looſe ſoil and rubbiſh, on the ſurface of ſuch mountains, or in the plains that are below them, or near them.

In the firſt of theſe ſtates (I mean in the original veins) it is found but rarely. By far the greateſt part of it is collected from among looſe ſoil, and gravel, and ſands,—eſpecially from the gravel and ſands of brooks in ſome mountainous countries, and from the ſoil which is near to ſuch brooks. Alſo in the ſoil of plains formed by the rivers into which ſuch brooks empty themſelves, and in the ſands of ſuch rivers.

And when we examine the gold found in theſe different places, we find reaſon to be ſatisfied that it is brought down from the mountains by the gradual and long continued action of water and the atmoſphere on the materials through which it is diſperſed. The proofs of this are, that the nearer to the mountains it is found, the grains of it are in general ſo much the larger, and the rougher or leſs worn;—while ſuch of it as is found at a diſtance from the mountains, or from the higheſt parts of the country, always conſiſt of grains ſmaller in their ſize, and evidently ſmoothed on their ſurface, and worn by the attrition they have ſuſtained from the ſand and gravel, during the great length of time required for their being brought down ſo far. You have examples of this general fact in the gold which is found in the ſands of ſome of the rivers of France, of which an elegant and entertaining account is given by Mr. Reaumur in the memoirs of the academy for the year 1718.

We have alſo an example of the ſame fact in this country. Gold is found at Lead Hills, and in a diſtrict there called Ettrick Foreſt. The gold is all in the form of ſmall grains, diſperſed through the gravel of the brooks, and in the ſoil that is near them. It was thought an object of value a long time ago, when gold was dearer than now; and great numbers of hands were employed in collecting it. From ſome regiſters, it appears that in one year 48000l. Sterling value of this gold was coined in the Scotch mint. The grains are in gene-

ral the larger and rougher the higher up the country they are found. The farther we deſcend, they are more diſperſed and of a ſmaller ſize, and more worn and ſmoothed. The ſame thing alſo was obſerved by Baron Born in Hungary and Bohemia. This points out very evidently from whence this gold comes, which is thus found in the ſoil, gravel, or ſand, of theſe particular diſtricts or rivers. And there cannot be a doubt that the gold which has been lately found in Ireland has had the ſame origin. In thoſe hills that confine the valley and the brook around which it is found, there are certainly mineral veins containing gold: And they cannot be far diſtant, if I may judge from a ſpecimen I ſaw of the gold grains. They are ſo rough, and have ſo little appearance of being worn, that they cannot be far removed from their original veins.

From the manner in which gold is depoſited in ſands, &c. it will often appear to be accumulated in particular ſoils and ſands into much richer collections than what can be found in the veins themſelves from which it deſcended. The depoſits of this kind in ſome of the lately explored diſtricts of Spaniſh America, as they have been deſcribed by the viſitors, exceed all belief. According to ſome of them, a man can gather to the value of 200l. in a day, by waſhing the common ſoil in ſome of the valleys. The ſoil in which it is found muſt be conſidered as the relics of the rubbiſh of mountains, depoſited upon mountains which have been demoliſhed and waſhed away. One of the ſtrong proofs of the great antiquity of this globe is the conſiderable quantity of gold found in the ſoils and ſands of ſome diſtricts. It is a clear proof of an operation or proceſs which muſt have required a length of time that is far too great for our comprehenſion.

The ſize of the gold grains is extremely various. The greateſt part of them are very ſmall; ſome as large as the ſeeds of apples, and ſome much larger. The grains of the Iriſh gold are uncommonly large. Reaumur reports that a piece was ſhewn to the French Academy, ſaid to weigh 56 marks, or 448 ounces. Feuillée ſays he ſaw

one in the cabinet of Antonio Portocarrero which weighed upwards of 66 marks. Both pieces were aſſayed and found of different fineneſs in different parts of the maſs. One was of $23\frac{1}{2}$ carats, 23, 22. The other of 22, 21, $17\frac{1}{2}$. It is, however, rare to find pieces one ounce in weight. The largeſt in the Britiſh Muſeum is only 15 pennyweights. In Chili 5000 pound weight of the richeſt ore yields only 12 ounces, which is not quite one grain per pound. Ore is wrought there without loſs, if it contains one-ſixth of this. On the coaſt of Guinea, a man can gain ſeven ſhillings a day by waſhing the common ſands on the river banks. From half a ton of the richeſt part of the ſoil at Lead Hills, waſhed under my inſpection, the produce of gold was $11\frac{1}{2}$ grains.

In this manner, therefore, is gold ſeparated from its original matrix, and collected in certain places by nature. It remains to deſcribe how man provides this metal for himſelf, by imitating more or leſs, or by completing this operation. This deſcription will be extremely ſhort, becauſe the account already given of the peculiar properties of this metal, and of the ſtate of its ores, and of the operations in metallurgy, requires nothing but general indications of what is to be done.

The firſt operation is an imitation of nature. The native gold being in ſmall grains, either among the ſands and gravel, or perhaps bedded in the ſtony matters, the whole is pounded by mills, and then the ſand ſo formed is agitated with much water in buckets or baſkets or ciſterns, by ſtirring it with rakes; and by a ſlight of hand, acquired by practice, the lighter ſand, occupying the upper part of the water, is daſhed over the brim. The gold particles remain with the heavier ſand. This is alſo daſhed over, after ſtirring; but it falls on a long ſloping table covered with rug. The ſtream carries the lighter particles over all the rug, and off the table. The heavier matter ſticks in the rug; and a few grains of gold are found towards the upper end of it. Theſe are ſhaken or waſhed off from time to time, and added to

the heavieſt particles which remained in the baſkets or ciſterns. Thus all the grains are at laſt collected; but along with them much baſer metals, or their ores, which are alſo very heavy.

The next operation is roaſting this duſt, to drive off ſulphurous and arſenical matter which is combined with the baſe metals.

The whole is now triturated in tubs with a quantity of mercury, which diſſolves the gold and ſilver, and forms an amalgam. This operation is expedited by adding a quantity of water and of common ſalt. The water facilitates the labour, and alſo aſſiſts the mercury in throwing out the baſe metals. The common ſalt decompoſes the vitriolic ſalts which were produced by the roaſting and burning of the ſulphur.

In the next place, the greateſt part of the mercury is ſeparated, nearly pure, by ſqueezing the whole thin paſte through porous leather. The firm maſs which remains contains all the gold and ſilver, and a good deal of mercury. The laſt is got off by diſtillation.

The laſt operation is the ſeparation of the ſilver from the gold, and the refinement of both, by ſuch of the proceſſes already deſcribed as is ſuited to the proportion of the two metals, and the impurities with which they may be tainted.

And when the gold is found combined with the ores of other metals, that is, when ores of other metals are treated for the gold which they contain, proceſſes muſt be employed for ſcorifying theſe metals, in one way or another, whether by ſulphurating them, or by lead, till the gold and ſilver are left alone, to be treated as now mentioned. For a more particular account I muſt refer you to Agricola, Schlutter, and Born.

GENUS XV.—PLATINA, OR PLATINUM.

This metal was firſt brought to England in the year 1749 or 1750, by Dr. Brownrigg, who preſented it to the Royal Society.

He had got it from Mr. Charles Wood, aſſay maſter in Jamaica, who told him it came from ſome of the Spaniſh provinces in America, and that it had ſeveral of the qualities of gold, in conſequence of which it was very difficult to ſeparate it from that metal; and that the name given to it by the Spaniards was *platina*, or *platina del Pinto*, and *Juan blanco*. Platina is the diminutive of *Plata*, ſilver; and Pinto is ſuppoſed to be the name of a mountain or river or perſon.

Soon after it was known in England, ſpecimens of it were brought to other parts of Europe; and the attention of many chemiſts was engaged by it. They made many experiments, and wrote diſſertations on this metal; of which we have examples in thoſe publiſhed by Mr. Lewis in the Philoſophical Tranſactions for the years 1754 and 1755, and in his *Commercium Philoſophico-technicum*; Mr. Scheffer's paper in the Tranſactions of the Swediſh Academy for the year 1752; Mr. Margraaf's diſſertation in the Memoirs of the Royal Academy of Berlin for the year 1757, printed in the 1759; and a memoir by Macquer and Beaumé, in the Memoirs of the Royal Academy of Sciences at Paris for the year 1758, printed in the year 1763; and many more ſince that time.

Platinum, as brought from America, in looſe grains, of the ſize of coarſe ſand, moſt of them ſmooth on their edges and ſides, having the metallic opacity and luſtre, and a dingy white colour, not brighter than that of iron; and they are all attracted, more or leſs, by the magnet. But, intermixed with theſe grains of the platinum, there are generally others of a ſmaller ſize, which are plainly iron ore, or iron ſand. In ſome ſpecimens alſo, a few ſmall grains of gold are found; and Mr. Lewis alſo obſerved a little quickſilver adhering to the gold. Mr. Lewis therefore conjectured that the platinum is got in waſhing ſome ſoils or ſands for gold.

By the numerous experiments that have been made with this metal, it is now aſcertained that in theſe grains it is intimately and ſtrongly united with about one-third of its weight of iron, and it is

not eaſily refined. When rendered free from all admixture, it has a whiter colour, and is the heavieſt metallic ſubſtance known at preſent. Refined gold is little more than nineteen times as heavy as water: But refined platinum is twenty-two times the weight of that fluid. Even in its natural ſtate, the ſpecific gravity of it is very uncommon. It is ſixteen or ſeventeen, or when the picked grains are tried, eighteen times as heavy as water.

When refined, it is alſo very malleable and ductile; although in its natural impure ſtate it has but a very ſmall degree of malleability.

One of the moſt extraordinary qualities of this metal is its reſiſtance to the action of heat, when applied with the purpoſe of melting it, without the addition of other metals. Macquer and Beaumé kept it in the greateſt heat of a porcelain kiln, and in a glaſs-houſe furnace, without making any change on it. The fuſion of it was at laſt accompliſhed, however, by Mr. Macquer, by employing the intenſe heat of Vilette's ſpeculum, and the great lenſe belonging to the Academy, both of which exceed the beſt furnaces, in the intenſity of their heat. Mr. Lavoiſier alſo ſucceeded with the blow-pipe, and with other fuel, by employing oxygen gas.

It poſſeſſes another ſingular property, that of compacting or welding, by the blows of a hammer, in the ſame manner as iron; and thus it may be brought from the ſpongy ſtate in which it is left by the proceſſes for refining, to the utmoſt denſity and compactneſs.

In the further proſecution of theſe experiments with heat, and in thoſe that were made with ſolvents, platina was found to have the ſame degree of power to retain its metallic form and purity, and the ſame diſpoſition to recover them when loſt, that ſilver and gold have.

It ſuffers no change from the action of air and heat; nor is it affected by nitre in the fire. Crude platinum, or the grains in their natural ſtate, are corroded and calcined by melted nitre; but it is evidently the iron which they contain that is attacked by the nitre,

and, when the platinum is once completely refined, the nitre has no power to calcine it. This metal alſo reſiſts the calcining powers of heat and air, in cupellation with lead. It not only remains unchanged, like ſilver and gold, while the lead is changed into litharge, but defends a portion of the lead from being calcined equal to about one-fifth of its own weight.

Thus, by its reſiſtance to the action of oxygen, it bears a reſemblance to ſilver and gold. But, upon the whole, it agrees more with gold than with ſilver.

It is ſimilar to gold by reſiſting the action of pure ſulphur, and conſequently of the ſulphuret of antimony, which can therefore be employed to aſſiſt in refining it from iron; but the metallic part of the antimony adheres to it afterwards very ſtrongly.

But, though the platinum cannot be united with pure ſulphur, it can, like gold, be diſſolved by the melted ſulphuret of potaſh, though not ſo eaſily.

None of the acids, in their ordinary ſtate, act on platina, in whatever manner they are applied, whether in their common form, or that of hot and dry vapours, by cementation. Like gold, it can only be diſſolved by oxygenated muriatic acid, or by aqua regia; commonly by aqua regia compoſed of equal parts of aquafortis and muriatic acid. Such an aqua regia will diſſolve about one-twelfth, or one-ſixteenth of its weight by digeſtion, or one-eighth by cohobation, according to Lewis. It has little cauſticity, and it ſtains the ſkin an indelible brown.

When this ſolution is evaporated for cryſtallization, it affords ſmall cryſtals like grains of ſand, of a deep yellow or red colour, and ſometimes opaque. When they are waſhed and dried, they require more boiling water to diſſolve them than five-hundred times their weight. The ſolution is yellow, and depoſits a pale-coloured and very light ſediment, ſuppoſed by Bergmann to be iron.

The ſolution of platina ſhews alſo very particular properties, when

we add to it alkaline ſalts, in order to precipitate the platina. Profeſſor Bergmann made many accurate experiments with it in this way, and has been much more ſucceſsful than Mr. Lewis in diſcovering the manner in which alkalis act on the ſolution of platinum. You will ſee his account of theſe experiments in his diſſertation on this metal.

I ſhall at preſent mention only the moſt remarkable properties by which this ſolution differs from that of gold.

1ſt, One remarkable difference is obſerved in the effect of ſal ammoniac on it. The ſolution of ſal ammoniac, or muriat of ammonia, in water, produces no perceptible effect on the ſolution of gold. But when a ſaturated ſolution of this ſalt is added to the ſolution of platinum, an orange-coloured precipitate is inſtantly formed, which experiments have ſhewn to be the platinum, or a part of it, combined with a ſmall portion of the ammoniacal muriat. This precipitate is ſtill diſſolvable, though with difficulty, in a large quantity of water.

2d, We find a difference between the ſolution of platinum, and that of gold, when we mix them with alcohol, æther, or the aromatic oils. Theſe fluids make the gold ſeparate ſooner or later from the acid in its bright metallic form. But when they are added to the ſolution of platinum, no ſuch effect is ever produced.

3d, This ſolution alſo differs from the ſolution of gold, by the manner in which it is affected by other metals, or their ſolutions, particularly by the ſolution of the ſulphat of iron, and the ſolution of tin. Both of theſe precipitate gold, and the ſolution of tin, in particular, precipitates in the form of the fine purple for enamels. But neither has any effect upon the ſolution of platinum. Theſe differences are the foundation of the methods by which theſe two metals can be completely and exactly ſeparated from one another.

One of the points to which Mr. Lewis was moſt attentive in ſtudying the nature of this metal was, to learn the conſequences of mixing it with other metallic ſubſtances. As it was not fuſible alone, the only manner in which it could be applied to uſe, appeared to be by mix-

ing it with other metals, which might have the power to diſſolve it in the fire, and to unite with it, ſo as to form uſeful mixtures. But he got no products that promiſe to be uſeful, except with copper, a mixture of moderate toughneſs, extremely hard, and which does not tarniſh; and with iron, a mixture of extraordinary ſtrength and hardneſs.

Such mixtures, however, afford us the only means of manufacturing it. They render it fuſible, and thus it may be moulded. The other metals may then be abſtracted, by various proceſſes, leaving it pure, but porous or ſpongy. In this ſtate it may be compacted and rendered perfectly ſolid, by forging, and thus manufactured into any ſhape. By ſuch proceſſes platinum becomes one of the moſt valuable metals that we know.

It unites readily with biſmuth,—moſt eaſily of all with tin, flowing very thin; alſo with lead; and forms a metal which will not ſcorify, nor be abſorbed by the cupel.

Dr. Lewis's principal purpoſe, by theſe mixtures, was to learn the conſequences of mixing platinum with gold, in different proportions.

The reaſon of his having this object in view was, that the platinum was conſidered as capable of being mixed with gold, ſo as to commit great frauds in traffic, without the poſſibility of detection by the common trials of the purity of gold, or of the quantity and nature of its alloy.

He therefore mixed it by fuſion with gold, in many different proportions. But, in general, it debaſed the colour and the malleability of the gold ſo much, even when it was only one twenty-fourth part of it, that he concluded that no great frauds could ever be committed by employing the grains of platinum for the adulteration of gold. And methods are now well known, by which we can eaſily refine gold that has been adulterated with platinum. We can eaſily therefore detect ſuch frauds, and learn the amount of them. The

beſt of theſe methods is the one invented by Mr. Scheffer of Sweden. The adulterated gold muſt be diſſolved with its uſual ſolvent, the nitro-muriatic: And we muſt then add a ſolution of the ſulphat of iron. Every atom of the gold is quickly precipitated, while every atom of the platinum remains diſſolved. We muſt then wait until the gold has completely ſubſided; and afterwards, pouring off the liquor, we muſt waſh the precipitated gold with repeated waters, and great care to avoid loſs. And laſtly, being dried, it is eaſily melted into a maſs with a little borax and nitre.

It may be remarked, however, with reſpect to Mr. Lewis's experiments on the mixtures of platinum with gold, that they are imperfect on this account. He made uſe of the platinum in its native ſtate, in which ſtate it is always mixed with iron; and the gold which he alloyed with platinum was therefore alloyed with iron at the ſame time. Later experiments have ſhewn that the quantity of iron in native platinum amounts to one-third of its weight: And theſe metals are ſo ſtrongly and cloſely combined together, that it is only of late that methods have been diſcovered for ſeparating the iron.

The moſt ſucceſsful methods that I have heard of are theſe:

One way is, to diſſolve the grains in the nitro-muriatic ſolvent, and precipitate the iron from the ſolution, with Pruſſian alkali. The pruſſiat of ſoda is the beſt for this purpoſe. This is a moſt effectual precipitant of iron, and produces no effect on the diſſolved platina, provided no more be uſed than enough to precipitate the iron. The ſolution of platina, thus freed from the iron, may next be evaporated to dryneſs; and the dry matter, expoſed to a violent heat, gives the platina pure.

A ſecond way is, after diſſolving the grains of platina, to precipitate the ſolution with a ſolution of ſal ammoniac, and then expoſe the orange-coloured precipitate to a violent heat, by which the ſalts that adhere to it are evaporated, and along with them any ſmall portion of the iron which may adhere to the precipitate.

A third method which has been practiſed with ſucceſs, and is the cheapeſt, is to refine it with arſenic. Platina, white arſenic, (or rather the arſeniat of potaſh) and tartar, in equal quantities, are melted by a violent heat, and form a very brittle white mixture, of metallic luſtre. This is expoſed to heat and air under a muffle, which diſſipate the arſenic and the iron in vapour, leaving the platina pure, to be compacted by the hammer.

Fourthly, Mr. Macquer found that it could be refined with lead by cupellation. But a moſt intenſe and long continued heat is required to evaporate the laſt portion of the lead from it. This method can only be applied in the refinement of a very ſmall quantity of it. From a larger quantity it would be impoſſible to evaporate the laſt of the lead. *(See Lewis's Commercium Philoſophico-technicum.)*

And laſtly, ſome of Mr. Pelletier's experiments with phoſphorus point out another method of refining it, which he ſays is eaſily practicable. He heated the grains of platinum in a crucible, and then threw in ſome bits of phoſphorus. The phoſphorus inſtantly penetrated the grains, and formed a fuſible metallic compound,—a phoſphoret of platinum. If this compound be expoſed to a ſtrong heat for ſome time, the phoſphorus is gradually burnt, and with it the iron, which forms a ſcoria or ſlag with the melted acid of the phoſphorus. The platinum is thus purified, but is no longer fuſible; and it remains very ſpongy, with the ſcoria adhering to it, partly on its ſurface, and partly in its pores. He therefore gives it a ſtrong heat, and ſuddenly compreſſes it in that ſtate with the blows of a very heavy hammer, ſuch as is employed in the proceſs of refining iron. This effectually compacts the platinum, forces the ſcoria out of its pores, and makes the parts of it unite together *.

This method of compacting platinum, and uniting the parts of it by

* Would not cementation with charcoal and bone aſhes, or the ſtone mentioned in page 268, accompliſh this purpoſe, without the expence of preparing the phoſphorus, —and thus afford a very eaſy method of manufacturing this uſeful metal?

EDITOR.

percuſſion, when ſtrongly heated, was firſt ſuggeſted by Mr. Beaumé; and it muſt be employed in every caſe in which this metal is refined. We cannot unite the parts of it by fuſion with any heat that furnaces can give.

When by theſe proceſſes platina has been purified from all admixture, it has the colour of pure tin, is very malleable, growing rigid by the hammering, but may be ſoftened by annealing. In this ſtate, its denſity or ſpecific gravity is from 20 to 22.

It is now to be hoped that this metal will be imported more freely into Europe, and that the mining grounds in America in which it is found will be opened again. The Spaniſh government at firſt prohibited the collection and importation of it, from apprehenſions that it would embarraſs their commerce in gold, by giving opportunity for frauds not eaſily detected. But there is no reaſon now for ſuch apprehenſions and precautions, ſince methods have been diſcovered for detecting the ſmalleſt quantity of platinum mixed with gold, and for eaſily ſeparating theſe metals from one another. And were the properties of platinum more fully inveſtigated, methods for working it eaſily into utenſils might be diſcovered, and then it might juſtly be conſidered as one of the moſt uſeful of the metallic ſubſtances. Its reſiſtance to the action of fire, together with its incorruptibility and cleanlineſs, would render it valuable for domeſtic purpoſes. The chemiſts already employ it on account of theſe qualities in ſome of their nice experiments and proceſſes. *(See Note 32. at the end of the Volume.)*

CLASS V.

OF WATERS.

IN former parts of this courſe, we have had already opportunities to notice the important and numerous uſes of water in the ſyſtem of the univerſe.

It is ſaid of ſome of the ancient philoſophers, that they ſuppoſed all things derived their origin from water. And it is true that the exiſtence of all the numerous tribes of vegetables and animals depends upon it. And when we examine the materials of which they are compoſed, water is always the principal part. But muſt we alſo ſuppoſe that water has given origin to the more ſolid and durable parts of this globe, the various earths and ſtones, the rocks and minerals of which the mountains and land are compoſed? Have all theſe been produced from water?

Whatever opinion we may form of the origin of theſe, it is at leaſt certain, that water has been the agent employed to give the regular arrangement in which many of them are found.

The appearance of numerous relics of ſea productions, and other traces of this fluid, are ſo frequent in the ſtrata of which this globe, ſo far as we can obſerve, is principally compoſed, that there is no room to doubt that the materials of theſe ſtrata have been arranged in that manner by the ſea. But ſome have concluded from theſe phenomena, and ſome other facts, that water has even furniſhed the matter

of the earthy and ſtony bodies,—that water is actually convertible into earth.

The firſt author who has mentioned the convertibility of water into earth is Mr. Boyle. He writes, that a friend of his was in poſſeſſion of three-fourths of an ounce of earth, produced from one ounce of water by the action of a long continued heat. And he relates ſome experiments made by himſelf, which convinced him that earth could be produced from the pureſt water by heat.

I repeated Mr. Boyle's experiment, by boiling and circulating boiling water a long time in a glaſs veſſel luted up quite cloſe, and I ſaw the appearance by which he was deceived.

Godfrey, the deſcendant of Mr. Boyle's aſſiſtant, thought he converted water into earth by triture. Wallerius alſo relates, in the Swediſh tranſactions, experiments in which, by triture, or agitation, or both, a quantity of ſiliceous matter was obtained from water. And Mr. Margraaf obtained it by diſtillation.

Lavoiſier's opinion is, that the earthy matter got by boiling of water in glaſs veſſels, is a part of the glaſs corroded by muriatic acid, preſent in all waters.

My opinion is, that this matter is a part of the glaſs corroded or penetrated by the water itſelf, which alone has the power to penetrate it, and even to diſſolve it, by length of time and aſſiſtance of heat. This explains the form and appearance of this matter, which is always in fine minute and thin ſcales, and alſo the change obſerved in the water, when the experiment has been continued a long time. It is ſaid to boil more like oil than like water. This proceeds from its holding a ſmall portion of the glaſs, or of the alkali of the glaſs, perfectly diſſolved. By my obſervations on the Geyſer ſprings of Iceland I found that water held ſiliceous earth in ſolution.

Another opinion however has been lately formed with regard to it, which is of greater conſequence, as it enables us to underſtand and explain a number of chemical facts. The opinion I mean is that which we have already adopted and applied in former parts of this

courſe; that water is not a ſimple elementary ſubſtance, but a compound.

This idea of the nature of water was ſuggeſted by Mr. Watt. (*Phil. Tranſ.* 1784.) Mr. Cavendiſh, however, was the firſt who gave it ſolid foundation and credibility, by his accurate examination of the conſequences of ſetting fire to a mixture of hydrogen gas and oxygen gas, in a veſſel in which they were confined. Mr. Lavoiſier and other French chemiſts, ſeeing the vaſt importance of this experiment in their ſyſtem, immediately repeated it, with much larger quantities of the materials, and with an excellent apparatus and the moſt ſcrupulous accuracy. They added ſeveral other experiments, which concur to eſtabliſh the opinion of the compounded nature of water. They alſo ſoon perceived and pointed out the important improvements which might be deduced from this diſcovery in the explication of many chemical facts, which were thus ſet in the cleareſt light. And ſince that time, the laſt finiſhing, we may ſay, has been given to this happy chain of experiments; and the compounded nature of water has been ſtill further illuſtrated, by the capital experiment of the Dutch ſociety of chemical philoſophers, who reſolved water into its two conſtituent parts, without making any addition to it whatever, but the matter of heat, collected and condenſed by electrical operations *.

All this, however, has been already noticed in the preceding parts of this courſe. At preſent we muſt confine ourſelves to the examination of the variety of waters found in nature, and to an account of the means which chemiſtry furniſhes for inveſtigating their qualities and contents.

* I obſerve ſome authors complimenting the ſagacity of Sir Iſaac Newton, by ſaying that he conjectured from its great refracting powers, that it contained an inflammable ſubſtance. I have never met with this aſſertion by Sir Iſaac Newton; and it is ſurely a miſtake,—for the fact is, that water has the ſmalleſt refracting power of any liquid that we are acquainted with. Sir Iſaac indeed ſays, that the great refracting power of the *diamond*, makes him imagine that it contains inflammable matter. EDITOR.

The natural varieties of waters are produced by the union of various other ſubſtances, in different proportions, commonly very minute, with this fluid. And it is never found perfectly pure from theſe, though in ſome caſes it is very nearly ſo.

When we have occaſion for water quite pure, to be employed in nice chemical operations, we muſt procure it by art. We muſt chooſe good ſpring water, or rain, or ſnow-water, collected at a diſtance from the ſmoke of many houſes, and diſtil it until we have got two-thirds, or three-fourths, and reject the remainder.

The varieties of water found in nature may be all comprehended under the ſix denominations of

1. Rain water.
2. Fountain water, and well water.
3. River water.
4. Water of lakes.
5. Water of marſhes and ſhallow pools.
6. Sea water.

Of theſe natural waters, rain water, when properly collected, comes neareſt in purity to diſtilled water. It is water diſtilled by nature; and would be quite pure, but for the vapours of the atmoſphere. To have it in the greateſt degree of purity of which it is capable, it muſt be collected at a diſtance from the ſmoke of houſes, or other cauſes which occaſion vapours or effluvia to mix with the air. The rain water which runs from roofs, however, is very impure and ſooty. Sometimes too it has happened, that ſhowers of rain have fallen mixed with the ſtaminal duſt of plants, which has been miſtaken for ſulphur.

The waters of ſprings and wells conſiſt of rain water, which has ſoaked through crevices and the more porous parts of the earth, until it has been ſtopped in its progreſs downwards, by impenetrable ſtrata of clay or other matter, and breaks out again in ſome lower part of the earth's ſurface.

The opinion which was once formed by ſome philoſophers concerning the origin of ſprings, is very abſurd,—that they are fed by the ſea; that the ſea water filtrates through the pores of the earth, and aſcends through the interior parts of the high lands and mountains; that the ſalt is ſeparated from it during this filtration, and that the water breaks out at laſt to form the ſprings. It is abſurd to ſuppoſe that the water can aſcend in this manner, contrary to its gravity, or that the ſalt can be ſeparated by filtration. It is plain that rain water falls moſt plentifully upon the mountains and high lands; and as a great part of it is abſorbed, and penetrates into the porous parts of them, it is abundantly ſufficient to account for the origin of ſprings. And we have a proof from the experience of miners: The deeper they go they meet with leſs water.

Spring water muſt therefore neceſſarily be leſs pure than rain water, as the water may find various ſubſtances in its way through the earth, which it will diſſolve and partake of. Some ſprings, however, give a water remarkably pure. Such are thoſe which are filtrated through ſandy and gravelly ſoils, or through mountainous countries, compoſed of harder and more undiſſolvable ſtones. Others contain a variety of matters; and theſe ſometimes in conſiderable quantity, and of ſuch a nature as to give them medicinal efficacy. For this reaſon, after we ſhall have ſhortly conſidered the other more general varieties of natural waters, we ſhall return to the varieties of ſpring waters, and explain them more particularly, with a view to point out the proper method for examining mineral ſprings, and for diſcovering the principles they contain.

The water of rivers is compoſed entirely of the waters of ſprings, and of ſuch rain water as runs along the ſurface of the ground, without ſinking into it. It is therefore various in different places. Thus the water of rivers which paſs through very large cities, as the Thames does, becomes ſo loaded with animal and vegetable matter, as to be ſuſceptible of a high degree of corruption. In general, however, the

water of thoſe large rivers which are not expoſed to ſuch cauſes of impurity, though often troubled with atoms of mud and clay, when refined from theſe by reſt or filtration, are rather more pure and wholeſome than the water of the greater number of ſprings or wells. The reaſon ſeems to be, that they are compoſed partly of rain water, which has not penetrated the ſoil, partly of the water of ſprings, which, while it runs a conſiderable way along the ſurface to join great rivers, becomes generally purer. Some of the principles it contains are volatile; a greater number are diſſolved in the water by means of thoſe volatile ones, and are depoſited when they evaporate. Whether the purity of river water depends on theſe circumſtances or not, it is certainly very remarkable in ſome caſes.

The water of large lakes, having the ſame origin with river water, is equally pure, except in a few examples of lakes ſituated in countries which abound with ſalt; and is in general much more tranſparent, in conſequence of its ſtagnation, which allows all the muddy particles to ſeparate to the bottom. But ſmall pools and marſhes, and other ſhallow collections of ſtagnating water, are in general very impure and unwholeſome. The heat of the ſun has a ſtrong effect upon theſe, and occaſions quick and multiplied ſucceſſions of animal and vegetable productions in them. The vulgar have been aſtoniſhed and terrified at the ſight of a red colour which ſuch waters ſometimes aſſume, as if ſuddenly changed into blood. This ariſes from inſects. The putrid damps which ariſe from ſuch waters in hot climates, or rather from the marſhes which they leave when they dry up, are cauſes of numerous diſeaſes, agues, dyſenteries, &c.

The laſt variety of water which we enumerated, ſea water, is ſtill farther removed from the ſtate of purity than any of the former. Near the ſhores eſpecially, it is not only rendered impure by the muddy particles brought into it by the rivers, and thoſe ſtirred up and kept afloat by the waves; but as it contains innumerable animals, theſe muſt contribute, by their different excretions, to its impurity.

The admixture, however, by which it is the moſt remarkably diſtinguiſhed from pure water, is that of different ſaline ſubſtances, which it contains in very conſiderable quantity, in conſequence of which it has a ſtrong taſte, and is totally unfit for the uſe of man, and other land animals.

The nature of theſe ſalts, and ſaline compounds, which ſea water contains, has been inveſtigated by different chemiſts.

Firſt, Dr. Gaubius of Leyden, who made his experiments upon 50 pound of the ſea water, and has publiſhed them in his *Adverſaria*.—From 50 pound of 16 ounces Troy weight of ſea water, Gaubius got,

	oz.	dr.	gr.
Common ſalt, ſome of it impure	20	4	1
Selenite, and what he calls *alumen muriaticum*	1	1	0
Sal dictum Glauberi	2	4	0

Bergmann examined ſea water, taken up for him by Mr. Sparmann from a depth of 60 fathoms, in the latitude of the Canary Iſlands. He obtained from it,

	oz.	dr.	gr.
Common ſalt	37	5	26½
Magneſia muriata	10	2	14
Gypſum	1	1	44½

He examined it very ſcrupulouſly for magneſia vitriolata, but found none.

Dr. Higgins got from ſea water of our climate,

	oz.	dr.	gr.
Common ſalt	23	3	36
Magneſia muriata	10	1	12
Gypſum	1	1	44

To imitate ſea water, ſuppoſe 50 pound of it to contain 25 ounces of common ſalt, and 10 ounces of muriat of magneſia. Each gallon Engliſh will contain four ounces of common ſalt, and 13 drachms of muriat of magneſia, which 13 drachms of muriated magneſia will probably be contained in 26 drachms of what is called oil of ſalt.

Dr. Higgins remarks that the magneſia ſalita appears to be the moſt efficacious ingredient in ſea water. The proportion of it to the ſea ſalt is as eight to 18½. And as perſons are cured of diſeaſes by ſea water, who eat ſea ſalt every day of their lives with their food, there is no reaſon to impute their recovery to the ſea ſalt.

It is uſual, therefore, in the practice of medicine, to imitate ſea water with a mixture of common ſalt and purgative ſalts diſſolved together; and the ſolution may be made ſo ſtrong that two ſpoonfuls, or a little more, may prove a doſe. But to reſemble ſea water, it ſhould always be greatly diluted when taken.

Sea water proves a uſeful medicine in ſome caſes, though taken in ſmaller quantities than what prove purgative. It is thought, when taken in this manner, to have ſome efficacy in removing obſtructions and tumours of the lymphatic glands. And ſome have imputed theſe effects to its ſeptic power, whereby it diſſolves concretions of the fluids. It contains leſs than Sir John Pringle's ſeptic quantity of common ſalt. But its medical efficacy does not appear to me in this light. Putridity weakens the power of the vital or animal principle, and increaſes all diſeaſes. I ſhould rather impute it to a general ſtimulus, by which it promotes all the ſecretory motions in the body. It is certainly in ſome meaſure by a ſtimulus exerted upon the ſkin, and by which it promotes perſpiration, that bathing in ſea water has been ſo beneficial in theſe and other diſeaſes.

Such is, therefore, the general outline of the variety of natural waters. To return now to the waters of ſprings.—

In order to give you a general view of the variety which occurs among ſpring waters, I muſt, in the firſt place, enumerate the different ſubſtances which have been found in them by chemical experiments, and mention ſome remarkable qualities which ſome of them are known to poſſeſs.

Thus, *1ſt*, Some are warmer than the medium heat of the latitude in which they are found.

The water of common ſprings always has at its ſource the medium temperature of the climate in which it is found. In this country, this medium temperature is 48° ; in London 52° ; about Paris 55° ; farther ſouth, higher. But ſprings are found in many places, the heat of which is conſiderably above theſe medium temperatures; and there is great variety in reſpect of this ſuperior heat. Some are boiling hot, others ſcalding hot, others only tepid, and ſo on. The moſt ſurpriſing particular in the hiſtory of theſe ſprings is the amazing quantities of hot water which ſome of them throw out, without the leaſt apparent variation of this quantity, or of the heat ; a certain proof that they receive their ſupply of water and heat from a great depth. Such are the ſprings at Bath.

The cauſe of this heat is a ſubject of many opinions. There are, doubtleſs, chemical changes going on in many watery ſolutions in the bowels of the earth, in which heat is extricated. But I cannot conceive any ſuch, where the reſult is pure water, ſuch as flows from the Briſtol hot well. In ſuch caſes, the cauſe of the heat is certainly ſubterranean fire. No other cauſe is adequate to the effect ; and we know that theſe fires exiſt, and have exiſted at all times. In agreement with this opinion, hot ſprings are moſt frequent in volcanic countries. There are many in Italy and in Iceland. Geyſer, in the neighbourhood of Hecla, in Iceland, emits an immenſe body of water by ſeveral openings. Two of them are very remarkable. The one, called the old Geyſer, throws out water by a perpendicular pipe, nine feet in diameter ; and it ſometimes throws the water up in the air 200 feet. Sir Joſeph Banks, &c. ſaw it riſe about 90. Alſo Mr. Stanley. *(Vide vol.* ii. *of Edin. Tranſ.)* Some hot ſprings are at a great diſtance from volcanoes. But how is ſubterranean fire ſupplied with air ? I may anſwer, that water carries air with it to theſe fires, and is converted into air by chemical operations ; ſome of which are known to us, while others are equally certain, although our chemical knowledge cannot yet explain them.

To proceed. Beſide this heat, found in ſome ſprings, we find alſo in many, as was formerly obſerved,

2*do*, Carbonic acid, the quantity of which is very various. Some are ſo much ſaturated with it, that it comes out of them as from ſome fermented liquors. It is generally attended by other admixtures.

3*tio*, The foſſil alkali is not uncommon, ſometimes combined in part with carbonic acid, but much more frequently with the muriatic. Some authors alſo mention the volatile alkali as having occurred. I believe, however, that if this ever happen, it is exceedingly rare.

4*to*, The ſulphuric, or the muriatic acid, or both together, are very often preſent in theſe waters; but they are always combined with the foſſil alkali, or with ſome alkaline earth, or with a metallic ſubſtance.

5*to*, The only alkaline earths hitherto diſcovered in ſpring waters are the calcareous and magneſia. They are either in the form of carbonats, that is, diſſolved in the water by means of the carbonic acid, or they are combined with the ſulphuric or muriatic acids.

6*to*, The argillaceous earth is rarely found diſſolved in theſe waters, but when it occurs, it is always combined with the ſulphuric acid.

7*mo*, Geyſer is the only example known to me in which the flinty earth is found in ſpring waters. It is diſſolved by means of fixed alkali.

8*vo*, Of the inflammable ſubſtances, we ſometimes find ſulphur, or ſulphurous gaſes, and more rarely, ſome of the foſſil oils. Theſe laſt appear moſtly in drops upon the ſurface of the water. The ſulphur, when it occurs, is more intimately combined or diſſolved, and this by means of fixed alkali, or of hydrogen, ſo as to form inflammable gas.

9*no*, Some of the metallic ſubſtances are the laſt which we need to enumerate among the contents of ſpring waters. And no more than two have, in my opinion, been certainly demonſtrated in their compoſition,—iron and copper.

Iron occurs very often, and is commonly diſſolved in the water by the ſulphuric acid, and ſometimes, as is ſuppoſed, by fixed air. Copper but rarely appears, and is always diſſolved by the ſulphuric acid.

Some authors mention alſo zinc and arſenic as occurring ſometimes, but I have not met with proofs of this. The ores of zinc are not liable to that vitriolization by the action of air, to which thoſe of iron and copper are often diſpoſed, and which converts them into compounds of metals and ſulphuric acid. And as for arſenic, though of itſelf ſoluble in water, it does not diſſolve without boiling heat. Were it ever to make its appearance in waters, the preſence of it in their compoſition would be but too manifeſt by their pernicious effects.

Theſe are the different ſubſtances which have been plainly demonſtrated in different ſpring waters. And they are found in the different ſprings in great varieties of number and proportion, only that in general the proportion of them to the water is very ſmall. Thoſe that predominate in any particular ſpring, give to the water particular qualities and a particular character, in conſequence of which, the ſprings reckoned medicinal have been diſtinguiſhed by phyſicians into a number of different kinds, and by different denominations, which I ſhall next explain.

1*ſt*, Thoſe that are warmer than the middle temperature of the place where they are found, called hot or tepid ſprings.—*Thermæ*.

2*d*, Thoſe in which carbonic acid predominates, ſo as to give them a ſouriſh taſte, and briſkneſs.—*Acidulæ*.

3*d*, Thoſe that contain an alkaline ſalt not completely neutralized with acid.—*Foſſil alkaline waters*.

4*th*, Thoſe which contain ſuch a quantity or variety of ſaline matters, as render them purgative.—*Purging ſprings*.

5*th*, *Chalybeate waters*.

6*th*, *Sulphurous waters*.

Theſe are the general diſtinctions of medicinal ſprings among phy-

ficians, who thus diſcriminate them by ſome of their ſenſible qualities or medicinal powers.

But ſome other qualities have been obſerved in ſpring or well waters, which have occaſioned other diſtinctions and denominations of them among common obſervers. Thus,

7*th*, Some are called *hard*, or ſprings or wells of *hard water*. Theſe do not diſſolve ſoap well, but produce a greaſineſs on the ſurface; and they are ill qualified for boiling vegetables, and for penetrating and diſſolving their ſoluble parts. The infuſions of tea, or other vegetables, in theſe are weak and bad. They contain a compound of ſome foſſil acid with other matter, by which it is not ſo completely neutralized as to prevent its acting on the alkali of ſoap.

8*th*, Some are called *petrifying waters*. They contain calcareous earth diſſolved by carbonic acid.

9*th*, Some are called *ſalt ſprings*. They yield common ſalt with profit.

10*th*, *Coppery ſprings* contain copper ſeparable by iron.

11*th*, *Bituminous ſprings*, are ſo called,—drops of bitumen being commonly found floating on their ſurface.

And now I have ſaid enough to enable you to form ſome general notions of the variety of ſpring waters which occur in nature. We ſhall next attend to the manner of examining them, in order to learn which of theſe ſubſtances now enumerated, or how many of them, they contain.

In examining mineral ſprings, 1*mo*, Obſerve the ſituation of the ſpring, and nature of the ſoil and country around it, and whether any minerals are near it, or within the diſtance of a few miles. They often receive ſome of their contents from a mineral vein.

2*do*, Obſerve its heat with a good thermometer, and alſo the colour, taſte, ſmell, and other ſenſible and obvious qualities of the water. Deep glaſſes are the beſt for ſhewing colour or clearneſs.

3*tio*, In order to the examination of the more fixed ingredients, evaporate one or more gallons of it with a gentle heat to dryneſs.

This evaporation may be performed, at laſt, in a ſmall China bowl, that the extract of the water may be the better collected together, and the more eaſily taken out; and the bowl ſhould be heated only with the ſteam of water. The quantity of the dry extract can be exactly aſcertained by weighing the bowl before and after the evaporation; and the different ingredients of it are to be inveſtigated by an analyſis.

We muſt next inveſtigate the materials which compoſe this dry extract, by the application of different ſolvents and other agents, ſuch as *1ſt*, Alcohol. *2d*, Diſtilled water applied cold. *3d*, Diſtilled water applied hot. *4th*, Acids. Alcohol diſſolves the compounds of magneſia or calcareous earth with muriatic acid, but leaves untouched all other compounds. A moderate quantity of cold water diſſolves all the other ſaline compounds, except gypſum; and gypſum is diſſolved and ſeparated from the mere earthy matter, by 500 times its weight of boiling water, or that quantity of diſtilled water boiled with it ſome time.

Theſe different ſolutions may afterwards be evaporated for cryſtallization, or we may eaſily learn, by other trials to be mentioned preſently, what acid and what quantity of it they contain, and with what matter this acid is joined.

4to, A ſet of experiments are to be made on the water itſelf in its entire ſtate: And they are made by adding different chemical agents, which produce remarkable effects on the various ſubſtances which the water contains, or are affected themſelves remarkably by them, to ſuch a degree that we are enabled in this manner to detect the moſt minute quantity of theſe ſubſtances. Of theſe experiments I ſhall mention ſome examples, while I deſcribe the manner of inveſtigating the contents of mineral waters.

I.—Experiments to diſcover the Carbonic Acid.

1. Attend to the obvious qualities which it produces, viz. briſkneſs like that of a fermented liquor, and a pungent ſouriſh taſte, both of which are loſt by expoſure to the air, eſpecially with agitation.

2. It ſtrikes a red colour with litmus, which diſappears by expoſure to the air for ſome time.

3. Lime-water, being mixed with ſuch aërated water, precipitates the lime, which will be rediſſolved if there be much of the air, and if we have not employed enough of the lime-water.

4. To meaſure the quantity, a bladder is tied to a bottle, and the air is expelled by heat.

This is the method which has been often practiſed, and which may be practiſed when we cannot do better, but it is not exact. A part of the air is very liable to eſcape at thoſe places where the bladder is tied; and ſome of it penetrates through the bladder, or is abſorbed by the water with which it is ſoaked. A more exact way is to fit a cork very cloſe to the mouth of the bottle, and then, making a hole through the cork, fix in it a bended glaſs tube. The bottle being then quite filled with the water, put in the cork, and make the extremity of the bended glaſs tube dip into a ciſtern of quickſilver, in which ſtands inverted a cylindrical veſſel, alſo filled with quickſilver. The air expelled from the water by heat, will riſe through the tube into this cylinder, and diſplace the quickſilver; and thus it is both collected and meaſured at the ſame time. And in order to learn the quality of it, we can apply cauſtic alkali, or lime and water to it, to know how much of it is carbonic acid gas, which will be quickly abſorbed; and we can afterwards examine the remainder *.

II.—Experiments to diſcover Alkaline Salts.

To learn, in the next place, whether or not there is any alkali not completely neutralized with foſſil acids, or combined only with the carbonic, we may uſe ſome of the vegetable tinctures, or infuſions of

* We may alſo learn its quantity with conſiderable accuracy, by the weight of the precipitate which it occaſions from lime-water,—having taken care that an exceſs of lime-water has been employed. The air may be eſtimated at eleven-twentieths of the dried precipitate. EDITOR.

flowers, that are the moſt eaſily affected by alkalis. The ſyrup of violets is that which is commonly uſed; but I find an infuſion of the flowers of mallow more convenient. The colour is produced exactly the ſame, whether the alkali be fixed or volatile; but we can eaſily diſtinguiſh which of the two it is, by a ſubſequent experiment with the muriat of quickſilver. And if we find it to be a fixed alkali, we are ſure it muſt be the foſſil alkali. The quickſilver, when oxydated, has a remarkably ſtrong attraction for volatile alkali,—a ſmall portion of which unites with it in this caſe; and forms with it, and with a ſmall part of the muriatic acid, a mercurius dulcis, inſoluble in water.

Theſe experiments, therefore, give indications of alkaline ſalts not completely neutralized with foſſil acids. But if alkalis be preſent, combined with one or more of theſe into neutral ſalts, they are beſt diſcovered and diſtinguiſhed by examining the extract of the water obtained by evaporation, and the different ſaline compounds into which it can be analyſed.

III.—Experiments to diſcover Sulphuric Acid.

This is often preſent, combined with ſome other matter. With whatever ſubſtance it be combined, it can always be detected by the muriat or nitrate of barytes, the barytes having the ſtrongeſt attraction for the ſulphuric acid, with which it forms a compound inſoluble in water. To make this experiment quite ſatisfactory, however, we muſt add a ſmall quantity of nitric or muriatic acid, perfectly pure, or free from ſulphuric acid; for the barytes may be precipitated by a carbonat of alkali; but if this happen, the ſmall addition of pure aquafortis will rediſſolve it.

IV.—Experiments to diſcover the Muriatic Acid.

This acid can as certainly be diſcovered by the ſolution of ſilver with exceſs of acid.

We do not learn, however, by theſe trials, what matter theſe acids

are combined with; but this appears, either from ſome of the other trials we have to mention, or from the examination of the fixed matter obtained by evaporation.

I obſerved before, that theſe acids are hardly ever found in the waters in a non-ſaturated or pure ſtate; though this is ſaid by ſome authors, who have probably been impoſed upon by the taſte and qualities of the acidulæ or aëreal waters. But turnſol would detect them.

V.—Detection of Earths in Mineral Waters.

Earth, when preſent, is ſeldom any other than calcareous earth, or magneſia, or both, combined with ſome ſolvent, either carbonic acid, or ſome of the foſſil acids. I have always obſerved, that in the waters containing thoſe carbonats, there is alſo a quantity of the earth combined with ſome other of the foſſil acids. The part diſſolved by carbonic acid, is diſcovered by boiling the water in a clean veſſel. The acid is expelled, and the earth precipitates.

Bergmann ſays that the calcareous earth, ſuſpended by aëreal acid, ſoon ſeparates from the water by moderate boiling: But that magneſia, in the ſame ſtate, ſeparates gradually, during the whole time that the water is boiled or evaporated to dryneſs. Water fully impregnated with carbonic acid will diſſolve more than one-fortieth of its weight of magneſia, every ounce holding above twelve grains. The tufa formed by the evaporation of ſuch waters, has been generally conſidered as calcareous; but it always contains magneſia, and ſometimes a great deal. Strata of limeſtone are met with, containing ſo much that they are unfit for manure, and even pernicious. This is the caſe in the neighbourhood of Doncaſter.

The nature of the earth which ſeparates in this manner is determined by combining it with the ſulphuric acid.

There is another method, better fitted for detecting the ſmalleſt quantity of earth ſuſpended by means of carbonic acid. This is done by dropping into the water ſome ſolution of the acetite of lead. The

lead is precipitated, and the earth ſuſpended by the acetous acid. But as the lead would alſo be precipitated by a ſulphat, we muſt add ſome more acetous acid. This will rediſſolve the lead, if it has been ſeparated by means of an earth. But obſerve that ſaccharum ſaturni does not ſhew a ſmall quantity of earth, if there be much carbonic acid in the water.

When the earth preſent in water is diſſolved by ſome of the foſſil acids, it may be ſeparated by carbonat of fixed alkali, which however is beſt added after the water has been evaporated to one-fortieth, or one-fiftieth, or rather after it has been evaporated to dryneſs; the ſoluble parts of the reſiduum being rediſſolved with diſtilled water, and the alkali added to this ſolution.

The nature of the earth is determined, 1*ſt*, By diſtilled vinegar applied cold, which will diſſolve calcareous earth, or magneſia, but not argillaceous earth.

2*dly*, By ſulphuric acid, which precipitates the calcareous earth from the vinegar in form of gypſum, but with magneſia forms a ſoluble compound.

Profeſſor Bergmann alſo recommends the oxalic acid, or the acid of ſugar, as a means for detecting the ſmalleſt quantity of the calcareous earth in particular, and in whatever manner it be diſſolved. It is ſure to unite with this acid, for which it has a much ſtronger attraction than for any other, and always forms an inſoluble compound. And this is perfectly true. The precipitation, however, is not ſo quick, or ſo remarkable, as in ſome of the experiments already mentioned, eſpecially with the acetite of lead.

If there be any ſiliceous earth diſſolved in the water, we ſhall be ſure to find it in the matter which the water affords when evaporated to dryneſs. After we have extracted the ſaline compounds and ſalts from that matter by alcohol, and by diſtilled water, applied firſt cold, in moderate quantity, and afterwards hot, in large quantity, mere earth will remain, which muſt be treated firſt with diſtilled vinegar,

which will diſſolve calcareous earth or magneſia; afterwards with ſome of the foſſil acids, which will diſſolve the argillaceous earth, if there be any. But if a quantity of tender, light, and ſpongy earth remain, on which the acids produce no more effect, there is reaſon to think that it is ſiliceous, and we can aſſure ourſelves that it is ſuch, by mixing it with an equal weight, or one-half of its weight, of dry carbonat of ſoda, and heating this mixture ſtrongly with the blow-pipe in a platina ſpoon. If the earth is ſiliceous, it will melt into glaſs.

VI.—Detection of Sulphur.

Having now ſhewn the means for diſcovering the preſence of ſalts and of earths, in the compoſition of mineral waters, the means for detecting the preſence of ſulphur are next to be deſcribed.

Sulphur has been found in two ſtates in ſulphurous waters: 1*ſt*, Either combined with an alkali, and forming an alkaline ſulphuret, (this I believe is exceedingly rare): or, 2*dly*, In the ſtate of a ſulphuret of hydrogen, or ſulphurous hydrogen gas, which, you know, is ſoluble in water.

The nature of this compound was firſt inveſtigated by Profeſſor Bergmann. He alſo ſhewed that it can be prepared by art, and ſo combined with water as to form a ſulphurous water of this volatile kind.

The indications of a ſulphurous mineral water are,

1*ſt*, Odour of hepar ſulphuris, perceived on approaching the ſpring. This is a ſure and nice indication.

2*dly*, A common trial is to put a piece of ſilver into the water, which is quickly tarniſhed and blackened. I find that other metals are fitter, *e. g.* lead is quickly blackened.

3*dly*, A mark made with acetite of lead, or tartrite of biſmuth, on paper, is exceedingly effectual and ſure. A true hydro-ſulphuret, diſſolved in water, (that is, a volatile ſulphurous water) blackens theſe ſubſtances very ſpeedily, even when brought very near them; and

they do this without ſuffering any decompoſition, indicated by milkineſs or turbidneſs. But a ſulphuret of potaſh or ſoda diſſolved in water, though it blackens theſe ſubſtances as quickly, is always decompounded by it. To learn the quantity of the ſulphur,

1*mo*, If any part of the ſulphur is diſſolved in the water, and kept ſuſpended by an alkaline ſubſtance, a little of the ſulphuric or muriatic acid will precipitate the ſulphur, which, being afterwards collected on a filtre, can be weighed by itſelf. But theſe acids never precipitate the whole of the ſulphur from ſuch waters; a part of it being combined with inflammable air, and diſſolved in conſequence. And many waters have all the ſulphur which they contain diſſolved in this form. In this caſe the ſulphur cannot be precipitated by diluted ſulphuric or muriatic acid.

2*do*, But we have other acids that can precipitate the ſulphur in this caſe, and theſe are the ſtrong red nitrous acid, and the ſulphurous acid. The firſt was recommended by Bergmann, and the ſecond by the French chemiſts. This precipitation is ſuppoſed to be produced by the action of the oxygen of the acid on the hydrogen of the gas. Theſe two principles unite together to form water, and the ſulphur, when thus left alone, is not ſoluble in water. But there is a difficulty attending this account of the matter: for, if it be well founded, we cannot find a reaſon for this inefficacy of the nitric and ſulphuric acids to precipitate the ſulphur *equally well, or better*, as they contain more oxygen than the nitrous or the ſulphurous acid. Moreover, when the oxygen is taken from the ſulphurous acid, why is not the ſulphur which that acid contains precipitated alſo, along with that of the water? As this does not happen, Mr. Berthollet and Fourcroy ſuppoſe that only a very ſmall portion of oxygen is taken from the ſulphurous acid, or ſupplied by it; and accordingly, when the water is examined after the precipitation of the ſulphur, the ſulphurous acid is found ſtill exiſting in it.

3*tio*, Several metallic oxyds alſo can be employed to attract the ſul-

phur from theſe waters,—ceruſſa, or white lead, for example. Litharge alſo has the ſame power, and the oxyds of quickſilver, and ſome others, particularly white arſenic. Theſe oxyds act partly by their oxygen, which unites with the hydrogen of the gas, and partly by their own attraction for ſulphur.

4*to*, Some ſolutions of metals in acids are ſtill more convenient indicators, as they enable us to aſcertain the quantity of the ſulphur. One of the beſt for this purpoſe is the ſolution of muriat of quickſilver. An æthiops, or ſulphuret of quickſilver, is produced, from which we can eaſily ſeparate the quickſilver by acids, to have the ſulphur pure; or we can firſt weigh accurately the precipitate, then revive the mercury, and, by the quantity of it, know how much ſulphur was joined with it. You know that the muriat of quickſilver contains this metal highly oxydated. The oxygen unites with the hydrogen of the gas, and the quickſilver thus metallized unites with the ſulphur.

VII.—The only other inflammable ſubſtance which has been found in waters, viz. bitumen, is obvious to the ſenſes.

VIII.—Metals are the laſt of the ſubſtances we enumerated, as found in waters,—and iron is the moſt common. It is often combined with ſulphuric acid, ſometimes, however, with carbonic acid.

The poſſibility of diſſolving iron in water by carbonic acid, or fixed air, was firſt diſcovered by Mr. Lane, and communicated in the Philoſophical Tranſactions of the Royal Society.

In authors you will find the Pruſſian alkali recommended for detecting metals in general, and even for diſtinguiſhing them. It precipitates iron blue, copper of a red or coppery colour, and zinc white. There is, however, ſome uncertainty in the indication of this teſt. It is a very difficult chemical problem to prepare this alkali altogether free from iron. We have a better teſt of this kind by combining the tinging matter, not with alkali, but with lime. Lime-water boiled a little on Pruſſian blue, will completely deprive about one-thirtieth of

its weight of all the colouring matter, without taking up any martial oxyd, and is a very ſure and expeditious teſt of the preſence of iron. For this purpoſe, it muſt be carefully kept in well ſtopped phials, and even ſcreened from the light.

The appearance of ochre in the channel of the little ſtream formed by the water flowing from the ſpring, is alſo a very nice indication of iron.

Aſtringent vegetable matter, and eſpecially the gall-nuts of the oak, will diſcover an aſtoniſhingly ſmall quantity of iron in theſe waters. It ſometimes happens, however, that the dark colour does not appear when the powdered galls are added to a water which contains iron. This proceeds from an exceſs of acid, and is eaſily obviated, by adding a very ſmall quantity of alkali. We can make the colour appear and diſappear repeatedly, in a mixture of this kind.

As for copper or zinc, their appearance is very rare, and we need not have recourſe to this trial to diſcover them. There are others that are better.

For the art of imitating the different mineral waters which are eſteemed in Europe, and made objects of commerce, you may conſult Profeſſor Bergmann, whoſe work on this ſubject, and on the manner of analyſing mineral waters, is one of the moſt valuable he has left us. More lately, Mr. Fourcroy has publiſhed a laboured and accurate analyſis of a ſulphurous water in France, at Enghien, in which he has given many judicious and uſeful remarks on the uſe of precipitants in examining theſe waters.

NOTES AND OBSERVATIONS

BY THE EDITOR.

[*Note* 1. *p.* 41.]

I MUST mention here that it was diſcovered by Mr. Milner in 1787, that if this alkali be made to paſs through a red hot tube, along with vital air, (oxygenous gas) we obtain nitrous acid. The experiment was this: He put a quantity of a ſubſtance called manganeſe (much employed in glazing the coarſer black earthen wares) into a gun barrel, and making this red hot, he ſent this alkaline gas through it. It is well known that the manganeſe yields only oxygen gas by this treatment. I am informed that the French, availing themſelves of this diſcovery, procured ſaltpetre for their military operations, by paſſing common air (which contains oxygenous gas) through vapours which contain this alkaline gas. It appears, however, in this, and in many other inſtances of ſuch mixtures of gaſes, that the combination cannot be effected, unleſs one or other of the gaſes be mixed in the very act of its formation. The gaſes themſelves, in many inſtances, will not mix, even when red hot, when completely formed. This alkali alſo combines with ſulphur, forming a gas of a moſt abominable ſmell.

[*Note* 2. *p.* 63.]

The word was firſt employed by Van Helmont, and particularly to expreſs the vapour which eſcaped from liquors in the vinous fermentation. He aſcribes to this gas the effects of the Grotto del Cane, in Italy, ſo named from the number of dogs killed in that cavern by breathing it. With a ſkill and juſtneſs that is ſurpriſing, he explains many changes which happen in animal ſubſtances by the extrication of gaſes. He ſays that thoſe gaſes, into which many bodies are completely reſolved, do not exiſt in them in an elaſtic, but in a liquid, or even a concrete and ſolid form. He gives them the general name gas, but diſtinguiſhes ſeveral kinds, ſuch as gas ſilveſtre, (an epithet borrowed from Paracelſus), flammeum, ventoſum, pingue, &c. By gas, then, we are to underſtand a

perfectly inviſible elaſtic fluid, that can be contained in a veſſel, which expands by heat and contracts by cold, but is not condenſed by cold into a liquid or ſolid, as the vapours of water or of camphor. It is proper to add the firſt character, to diſtinguiſh gaſes from fire, light, and the ſuppoſed elaſtic atmoſphere of magnetic and electric bodies. Some chemiſts would except reſpirable air from the gaſes, and conſider them as all diſtinct from air. But it is not improper to employ gas as the object of chemical examination, and to call them airs, when we examine them mechanically.

[*Note* 3. *p.* 108.]

It is indeed a very improper denomination, on the principle by which it is pretended that the French nomenclature is regulated. It neither follows the rule adopted for the ſimple ſubſtances, nor that for thoſe of a ſecond order. It is not diſtinctive. For almoſt every aëreal fluid, except the oxygenous gas, is azotic, *i. e.* extinguiſhes the life of the warm blooded animals. Moreover, knowing the wonderful augmentation which the reſpiration of the nitrous oxyd makes in the vivacity and energy of animals, it ſeems extremely incongruous to call its chief ingredient azote. Lavoiſier intended another name for it. Some experiments of Berthollet had made him hope to eſtabliſh it as the alkaline principle, as vital air was aſſumed by him as the acid principle, and thus to embrace, in one propoſition, the whole round of chemiſtry; but Mr. Cavendiſh's experiments put an end to this, ſeeing that it *muſt* be adopted as the *diſtinctive* ingredient of the nitrous acid. Yet he would not call it nitrogen, becauſe it was diſcovered to be alſo one of the two ingredients of volatile alkali. He gave this reaſon, and ſome hint of this little hiſtory, to Mr. De Luc, in converſation. But Mr. De Luc could not get more out of him, though few inquirers are more pertinacious. Perhaps Lavoiſier's hopes of making it the alkaline principle were not yet extinguiſhed.

[*Note* 4. *p.* 109.]

It is not improbable that electricity has ſomething to do here. The light of the electrical ſpark, viſible in a great extent of air between the diſcharging balls, is, I think, the indication of ſome chemical action going on in the whole of that extent; indeed, on the principles of the new chemiſtry, it cannot be any thing elſe. There is no ſuch thing as the transference of ſomething luminous from the one body to the other. There is a decompoſition of oxygenous gas taking place wherever we ſee the light. It ſeems to be ſimultaneous, but it is ſucceſſive and amazingly rapid. There is a ſmell accompanying all electrical experiments. This ſmell is alſo a ſtrong indication of ſome chemical action. But this is very diſtinct, or peculiar, and has no reſemblance to the ſmell in any proceſs with the nitrous acid. I ſuſpect therefore that electricity acts otherwiſe than mere-

ly by exciting a great heat. Great heat will produce a combination of oxygenous and azotic gaſes, if either of them be taken in its naſcent ſtate, *i. e.* in the very act of its extrication; but not when they are completely formed. This may ariſe from the conſtituent parts of the completely formed gas. When nitrous acid is decompoſed by detonation, much light and heat are diſengaged. It may happen that, in the formation of theſe gaſes, the mutual attraction between them may be very great, while both or either of them are unprovided with the heat or light required for their gaſeous form, but may be much weaker when they are furniſhed with it. This will even be analogous to the greateſt part of chemical combinations. The effect of electricity may be to diſcharge part of this heat and light from the air in which it is ſeen. But, on the whole, there are ſeveral phenomena in the relations of azotic gas which are not eaſily reconciled with our preſent notions, and even affect conſiderably the whole ſyſtem of Lavoiſier *.

I may here mention another peculiarity of this gas. It communicates the green fæcula to plants growing in the dark, which would otherwiſe be white. This appears from a ſeries of experiments by Sennebier.

[*Note* 5. *p.* 122.]

The order of compoſition expreſſed by this termination *et*, (*etum*, in Latin), has not been yet explained by Dr. Black. It means, in the French nomenclature, the combination of a radical, ſuch as ſulphur, carbon, phoſphorus, &c. with any ſubſtance except oxygen, without an intermedium. Thus, we have the *ſulphuret of potaſh*, the *carburet of iron*, the *hydrogenous phoſphoret*, &c. But when the ſame radical ſubſtance is combined with potaſh by the intervention of oxygen, the compound is then a ſulphat of potaſh, or a ſulphite of the ſame, according as the proportion of oxygen is great or ſmall.

The ſulphat of potaſh is not, however, conſidered as a compound of theſe ingredients, but as a compound of potaſh united with ſulphuric acid, which is occaſionally conſidered as a ſubſtance *ſui generis*, having affinities and properties truly diſtinctive, in which the properties of its ingredients, ſulphur and oxygen, are in ſome meaſure dormant. This was undoubtedly the way in which Mr. Lavoiſier conſidered theſe things. I apprehend that this is the only accurate notion that can be had of a true chemical combination, and that there is no ſuch thing as a compound of three ingredients, in which the primary properties of each are immediately efficient. Such compounds, however, are frequently ſpoken of by the new chemiſts, eſpecially in their attempts to point out the procedure of nature in the fermentations,—vinous, acetous, and putrefactive. But I know no ſubſtance in which the ingredients exert the ſame combining energies as if they were

* Many chemiſts of eminence imagine that its radical part is the ſame with that of oxygenous gas, and that the difference in its chemical qualities proceeds from a difference in the proportion of caloric combined with it. Others imagine that it has not caloric combined with it, but the matter of light; but theſe are all conjectures.

all ſeparate. They take this method, becauſe it gives them a vaſtly greater latitude in their explanations. But once this liberty is taken, you will ſcarcely ſee two chemiſts explain the phenomenon in the ſame way. Had the political ambition of thoſe whom Lavoiſier aſſociated with himſelf in his labours and honour, ſuffered him to remain at their head, he would have ſaved his followers from many embarraſſments in which they have involved themſelves by this manner of proceeding.

[*Note* 6. *p.* 213.]

I cannot omit mentioning in this place, that my colleague Dr. Daniel Rutherford read, in the year 1775, to the Philoſophical Society of Edinburgh, a diſſertation on nitre and nitrous acid, in which this doctrine is more than hinted at or ſurmiſed. By a ſeries of judiciouſly contrived experiments, he obtained a great quantity of vital air from nitric acid; about one-third of that quantity from the ſulphuric acid, as contained in alum; and a ſmall quantity (and this very variable and uncertain) from the muriatic acid. The manner in which it came off from the compounds, in various circumſtances, led him to think that the different quantities obtained did not ariſe from the different proportions in which it was contained in thoſe acids, but merely in the different forces with which it was retained. He therefore concluded that vital air was contained in all acids, and thought it likely that it was a *neceſſary* ingredient of an acid; and, ſeeing that it was the *only* ſubſtance found, as yet, in them all, he thought it not unlikely that it was *by this that they were acid*, and he points out a courſe of experiments which ſeems adapted to the deciſion of this queſtion. I was appointed to make a report on this diſſertation; and I recollect ſtating as an objection to Dr. Rutherford's opinion, "that it would lay him under the ne-"ceſſity of ſuppoſing that vitriolic acid was a compound of ſulphur and vital air," which I could not but think an abſurdity. So near were we at that time to the knowledge of the nature of the acids!

[*Note* 7. *p.* 243.]

Dr. Black's notes, from which he was accuſtomed to lecture on this ſubject, for the laſt four years of his teaching, are extremely imperfect, and conſiſt of nothing more than references to experiments by Prieſtley, Auſtin, Milner, Berthollet, and an intimation that the French chemiſts practiſed a certain proceſs to procure ſaltpetre for the army, and here and there a ſlight thread of reaſoning from the experiments. I think that I have found out all the experiments to which he refers, and I have put them down in the order in which they ſtand in the notes; but I confeſs that unleſs I greatly exceed any authority derived from the manuſcript, I cannot give that clearneſs that will ſatisfy a cautious mind. Nor can I adhere to the rule laid down in the beginning of this chemical hiſtory, namely, to employ in argument no ſubſtance of which the properties have not been pre-

viouſly diſcuſſed. I have availed myſelf of the notes taken by a young gentleman who attended the two laſt courſes of Dr. Black's lectures, ſo that I preſume that what I have inſerted in this place does not differ much from what he delivered.

[*Note* 8. *p.* 246.]

It muſt be confeſſed, that the evidence for this compoſition of ammonia is in a great meaſure hypothetical, even when the compoſition of water and of nitrous acid is fully acquieſced in; and the followers of Lavoiſier differ much among themſelves in the ways in which they explain the phenomena which are adduced as arguments. Having a number of ſubſtances before us, which exert mutual actions, it is plain that we can match or pair them in a variety of ways, and may ſelect that double exchange which ſuits our purpoſe. We do not, in many caſes, ſee clearly why either azotic or hydrogenous gas is not *always* produced. Mr. Berthollet obtained azotic gas, and Dr. Prieſtley obtained hydrogenous gas from ammonia by the electric ſpark. Nitrous ammoniac does not always yield azotic gas and water, but another gas conſiderably different. We aſk what becomes of the hydrogenous gas in Mr. Berthollet's experiment? It is ſaid that the mercury is always covered by a film of mercury combined with oxygen, and that this is detached by the hydrogenous gas and water formed. It is alſo ſaid that nitrous acid was formed in Dr. Prieſtley's experiment; but there is no proof of this offered; it is an aſſumption *on the authority of a previous theory*; and this, without having aſcertained the elective attraction which that theory neceſſarily ſuppoſes. The ſame gratuitous procedure is obſervable in many explanations given by the followers of Mr. Lavoiſier, in all caſes where they employ the decompoſition of water. They have not aſcertained, by experiments inſtituted on purpoſe, the double exchanges that are poſſible among the ſubſtances employed. I can point out inſtances which cannot both be poſſible,—and yet I ſee both employed.

[*Note* 9. *p.* 261.]

Two ounces of ſlaked lime, and one drachm of phoſphorus cut into very ſmall bits, were made into a ſoft paſte, which muſt be haſtily put into a ſmall earthen retort, having a ſwan neck tube luted into its neck. This is introduced into the ordinary pneumatic apparatus, as it is called, and heat is cautiouſly applied, on account of the exploſions which frequently happen. The gas ſoon comes over, and continues to diſtil for a great while. This quantity of materials will yield three Engliſh quarts of gas.

If a quantity of it be let up through water into the air, it gives a bright flaſh, and a fine ring of white ſmoke riſes from it. This combination was made by Dr. Raymond.—*Ann. de Chym.* x.

Dr. Pearſon at London lately made an experiment, which ſhews ſtill more diſtinctly

the nature and hydrogenous origin of this gas. He combined phoſphorus with quick-lime, and put the compound into water. While it ſlowly penetrates, and partly diſſolves it, a ſmall part of the water is gradually decompounded, the diſſolved phoſphorus attracting its oxygen, and allowing the hydrogen to eſcape; and this is collected in the upper part of the apparatus in its ordinary form, containing (but not always, nor in equal quantity) a ſmall portion of phoſphorus. The gas, accordingly, will not always kindle by ſimple contact with atmoſpheric air. It rarely fails to kindle in pure vital air; and in all caſes it kindles by any ſpark. The inference is plain.

This combination of phoſphorus and alkaline ſubſtances, is in many reſpects ſimilar to the combination of ſulphur with theſe ſalts, and like it, produces a hepatic gas, having ſimilar properties. This experiment of Dr. Pearſon illuſtrates all theſe hepatic phenomena.

[*Note* 10. *p.* 274.]

The proofs of this not being adduced in Dr. Black's manuſcript, and its properties being remarkable, and chiefly becauſe the mode of its formation is one of the complicated applications of the new theories, it ſeems neceſſary to mention ſome of the more direct and ſimple arguments.

Dr. Higgins, by paſſing the ſteam of water over melting ſulphur, produced ſulphurous acid and hydrogenous gas.

Mr. Gingembre, bringing the focus of the ſun's rays through a large lenſe on a piece of ſulphur incloſed by mercury in inflammable air, produced this gas in perfection.

Dr. Prieſtley, by paſſing a ſtream of inflammable air through ſtrong vitriolic acid boiling hot, produced this hepatic gas.

Dry hepar ſulphuris, made with cauſtic alkali or lime, when treated in a retort with great heat, does not afford this gas, but ſulphur; but if it be moiſtened, or has been prepared in the humid way, it yields hepatic gas in great abundance. Dr. Auſtin precipitated ſulphur from it by the electric ſpark. The remainder was inflammable air, of the lighteſt kind.

[*Note* 11. *p.* 275.]

This obſervation of Dr. Black's is very juſt, and the language of the French chemiſts in explaining theſe phenomena is a proof that they proceed without diſtinct notions of the ſubject. Fourcroy, for example, ſays, "L'acide ſulphureux decompoſe le gaz hydro-"gene ſulphuré, en ſeparant le ſoufre, parceque l'oxygene, en partie libre dans cet acide, "ſe porte facilement ſur l'hydrogene de ce gaz. L'acide ſulphurique ne produit pas le "meme effet." *Supp. p.* 76. Now, ſurely in their theory, the ſulphurous acid has no "*oxygene en partie libre*"—on the contrary it has *ſouffre en partie libre*. I may ſay the ſame thing of the nitrous or fuming acid. He ſays in the ſame page, that the dephlogiſticated

marine acid (acide muriatique oxygené) decompoſes this hepatic gas. Here I grant the " oxygene en partie libre." Surely in as far as the decompoſition depends on oxygen, the operation of the ſulphurous and nitrous acids ſhould be the reverſe of that of the oxygenated muriatic acid. In truth, this decompoſition embarraſſes thoſe chemiſts; and they differ exceedingly in the way in which they conceive it to be effected. Fourcroy, and the Dutch chemiſts of whom Dr. Black ſpeaks in the next paragraph, do it in one way, and in the *Annales de Chymie*, vol. 14. page 313, we have quite a different account of the procedure. Gren, a German chemiſt of great reputation, is of opinion that the theory is imperfect without another ſubſtance which he calls *firematter*; and with the help of this he ſolves all the phenomena very eaſily and elegantly. But there is no end to ſubſtitutions founded on ſuch fancies as this. It is like the æthers and other inviſible fluids, which the mechanicians have introduced, becauſe their explanations by impulſion cannot go on without them. Before we can proceed with ſafety in thoſe explanations which employ the decompoſition of water, a ſeries of experiments ſhould be made for aſcertaining the elective attractions of the radicals of the gaſes with a preciſion equal to what we have attained in the more familiar ſubſtances. Till this be done, we may form ingenious conjectures concerning the hidden operations of nature in bodies of a complicated nature, but we gain no confident knowledge. The followers of Lavoiſier, graſping at every thing, find no difficulty of giving what may be called a *narration* of this internal procedure, taking the combinations and decompoſitions in ſuch order as ſuits their purpoſe; and this is contrived ſo as to terminate in the ultimate combination which we all obſerve. This is not a very difficult taſk, even when we limit our combinations to two ſubſtances, and produce them by ſimple affinities. If we take compounds of three ingredients, as in the preſent caſe, and employ double affinities, our means of accompliſhing the *deſired* end are increaſed prodigiouſly, and there is nothing that can eſcape us. The new phraſeology is ſo ſignificant, that every epithet indicates an operation; ſo that our explanation has great appearance of a real knowledge of the facts. But that all this is little better than conjecture, and very precipitated and unwarranted concluſions, appears from this,—that two eminent chemiſts, explaining the ſame oſtenſible phenomenon, and employing the ſame agents, give quite a different *ſtory*, merely by taking a different order of ſucceſſion in the ſteps of the internal procedure. They therefore employ quite different combinations and decompoſitions. This cannot be, if the affinities of the ſubſtances, when in the ſame ſituations, be conſtant. Lavoiſier has rarely taken much liberty this way; but his more zealous followers ſet no bounds to their theories.

[*Note* 12. *p.* 312.]

It will be of ſome ſervice to us in our future conſideration of this ſubject, to recollect the well known fact, that any plant, the ſugar cane for example, will grow from a minute ſeed to maturity, yielding ſugar and every other production competent to its nature, if

planted in pure ſand, fed with diſtilled water, and having a free communication with the air and light, and a proper degree of warmth. The ſand in which it grew is neither diminiſhed nor changed in the ſmalleſt degree. It would ſeem, therefore, that we muſt expect nothing from alcohol but what is ſupplied from theſe ſources, viz. the water, the atmoſphere, light, and heat; and that it is to theſe that we are to look for the oxygens, hydrogen, azote, carbon, alkali, and every thing that we obtain from alcohol.

[*Note* 13. *p.* 317.]

Dr. Black has attended to thoſe circumſtances only of the proceſs which relate to the preparation of æther. It is therefore proper to mention, that, at the time when the white cloud preſcribes the damping the fire and changing the receiver, another ſingular product begins to form. This drops from the ſpout of the retort into the water in the receiver, and is the *ſweet oil of wine*, an oily, fragrant, and ſweet taſted fluid. With whatever care the proceſs is now conducted, the matter in the retort being now much hotter, the vapours of ſulphurous acid now riſe, and muſt be allowed to eſcape,—more oil comes over, but horribly tainted with theſe vapours, and growing more and more thick and dark coloured,—at laſt quite dirty. This is owing to a perfect charcoal, now formed in the retort, ſo light as to riſe with the vapours. At laſt, the matter in the retort becomes a dry, pitchy-like, ſpongy maſs.

[*Note* 14. *p.* 318.]

It would never appear in the fluid form in theſe climates, but in that of elaſtic vapour, did not the preſſure of the air keep its particles from flying aſunder. This muſt bring to our recollection Dr. Cullen's experiments, which were of ſo much uſe to Dr. Black for eſtabliſhing the doctrine of latent heat.

If a wide glaſs cylinder, fitted with a piſton, which is put half way down, be filled with the pure vapour of æther, kept of ſuch a temperature that it juſt balances the preſſure of the air, and if the piſton be then ſuddenly drawn to the top, the cylinder will be filled with a white cloud, which laſts for a ſecond or two, and then diſappears. This ſhews that it is not merely *capacity* for heat which fits the vapour for appearing in its more expanded form. This form is the conſequence, and not the cauſe, of the abſorption of heat.

[*Note* 15. *p.* 388.]

I cannot but think that peat, or the black moſs of the moors, is an approximation to coal. Peat is not found in many places; and no where abounds ſo much as in Scotland and Ireland. It is by no means enough for the formation of peat that the place be a wet

marſh, abounding in vegetable matter. In the immenſe diſtricts of Europe and America, ſuch ſituations are common; and we have impaſſable moſſes and ſwamps of vaſt extent, but theſe are not filled with peat, nor is the mud which fills them very inflammable. Accuſtomed to the bogs of Scotland, and little informed in natural hiſtory, I was much ſurpriſed at not finding ſimilar ſituations in the Canadian woods without peat; and this made me examine with attention the matter contained in thoſe bogs. Even where the vegetable remains were very abundant, and conſtituted almoſt the whole maſs, I found it very little inflammable, and altogether unfit for a fuel. And what I took particular notice of, the ſmell in burning was altogether unlike the ſmell of burning peat. This is quite peculiar to peat. I never ſaw peat in any part of North America, except in the neighbourhood of Louiſburg,—and there it was but a very ſcanty mixture of peat-earth with the mooriſh ſoil.

While the ſmell of all burning peat has a character by which it may always be known, there are conſiderable varieties; and theſe varieties ſeem to me to be ſuper-additions to the diſtinctive ſmell of peat. This is conſiderably like that of the moſt inflammable lean coal, and ſtill more like to that of jet, but not near ſo offenſive. The blackeſt, hardeſt, heavieſt peat, when the matter is almoſt an impalpable pulp, is the moſt inflammable, and leaves the ſmalleſt quantity of aſhes. This kind of peat has the heavieſt ſickening ſmell. Such is the peat at Caniſbay, in the north extremity of Scotland, juſt by John-a-Groat's Houſe. This, when dried, is ſo fine in its texture as to break with a ſort of poliſh, like a jaſper. Its ſmell in burning is not very diſtinguiſhable from that of cannel coal. The ſmell of the beſt Dutch turf, which is taken up from the bottom of ſalt water, reſembles that of the peat now mentioned very much.

I am inclined to think that a certain juice is neceſſary for the formation of a bog into peat. Perhaps this juice is the primitive bitumen. I ſuſpect alſo that it is always accompanied by vitriolic matter. Peat aſhes always contain a very great proportion of iron. I have ſeen three places in Ruſſia where there is ſuperficial peat moſs, and in all of them the vitriol is ſo abundant as to efflorеſce. One in particular, hard by St. Peterſburgh, ſhews it every morning on the clods, when the dew has dried off.

Peat moſſes form very regular ſtrata, lying indeed on the ſurface; but if any operation of nature ſhould cover this with a deep load of other matter, it would be compreſſed, and rendered very ſolid; and remaining for ages in that ſituation, might *ripen* into a ſubſtance very like pit-coal.

[*Note* 16. *p.* 407.]

Perhaps the fact would be more properly expreſſed by ſaying that when the effervеſcence produces hydrogenous gas, the French chemiſts, combining their theory of combuſtion with Mr. Cavendiſh's diſcovery of the compoſition of water, infer that the metal acted only on the water, and attracting its oxygen, ſets the hydrogen at liberty. When

azotic gas, or nitrous air, is yielded by the effervescence of a solution of metal in nitric acid, they say that the metal acted on the acid, attracting its oxygen, and thus liberating the azote. Before Mr. Cavendish's discovery, the solution of metals in the sulphuric and muriatic acids presented difficulties which greatly embarrassed the partisans of the new doctrine. This accounts for their anxious and laborious repetition of the experiments of Mr. Cavendish. Till this doctrine was firmly and accurately established, the theory of acidification was quite unsatisfactory. Nor did even the composition of water make it of extensive influence, till the proportion of the gases was exactly ascertained.

It must be acknowledged that the order in which metals appear to attract the acids in solution corresponds pretty well with the order in which they are oxydated by the action of heat and air. Zinc and iron precipitate all other metals from the nitrous acid; and these metals are more calcinable than most others. Tin, however, does not fall into its place in the order of solution: It is very calcinable. It is also pretty conformable to the same principle that zinc, iron, and tin, produce inflammable air, that is, decompose water by their strong action on the oxygen. But were this the sole efficient cause of this peculiarity of those metals, we should expect it in a much more remarkable degree in cobalt, magnesium, and tungsten, which calcine so rapidly by mere exposure to the atmosphere. Nay, the white oxyd of magnesium should do it. But none of these substances produce, as far as I can learn, inflammable air from diluted sulphuric acid, &c.

I would say farther that the application of this theory to the complicated cases of animal and vegetable substances is, in a great measure, gratuitous, till we shall have ascertained, not only the proportion of the ingredients, but also their elective attractions in all different temperatures. This seems peculiarly necessary with respect to the basis of the three gases, which act such important parts in these changes. Till this knowledge be attained with considerable precision, it will always be easy, by ringing the changes (so to speak) on oxygen, hydrogen, and azote, and by taking their several actions in any order of succession that we please, it will, I say, be easy to explain any phenomenon whatever. I must add that some of those elective attractions appear to me to be such as to render some of the favourite explanations of these phenomena inadmissible. I think that I shall be able to give instances, before we get to the end of these lectures.

[*Note* 17. *p.* 414.]

These Dutch gentlemen do not choose to consider these facts as examples of combustion, because they say that there is no decomposition or change effected in either of the ingredients. It is a mixture, like that of sulphuric acid and water, in which also there is a vast extrication of calorique; because the capacity of the mixed is less than the sum of the capacities of the ingredients while separate. Or it is the extrication of latent

heat. They explain theſe facts in the ſame manner. There is indeed another caſe, in the mixture of metal with ſulphur, in which this explanation is very admiſſible, namely, the incandeſcence (and actual inflammation, if in the air) of mercury and ſulphur, in the preparation of cinnabar. But in the facts mentioned above there are very eſſential differences of circumſtances.

I have not ſeen the account which the Dutch chemiſts have publiſhed of theſe experiments, and have read only Van Mons's repetition of them, of which a very diſtinct abſtract may be ſeen in the *Analytical Review* for October 1795. I do not know, therefore, the preciſe ſtate of the compounds. This is certainly a chief circumſtance, with reſpect to the theory of the phenomenon. It was ſurely a very unexpected thing that zinc ſhould exhibit ſuch an appearance of inflammation, ſeeing that this metal contracts no union with ſulphur.

We muſt at any rate conclude from theſe experiments, that oxygen gas is not the ſole ſource of the light and heat which appear in the combuſtion of bodies, which ſeems to be a point of doctrine in the antiphlogiſtic ſyſtem of chemiſtry. The great heats produced during the ſolution of metals in acids, notwithſtanding the eruption of much gas containing oxygen, preſent, I think, a difficulty in this ſyſtem. It is ſomewhat leſſened by theſe Dutch experiments. For we ſee ſo much heat extricated as to produce ignition; and therefore may more eaſily conceive the change of capacity in ſolution to be adequate to the production of the ſmaller heats which appear in that proceſs.

The heat and light alſo, in all deflagrations with nitre, is another indication of a great quantity of caloric combined with oxygen and with azote in the nitre, in their ſolid form.

From ſuch facts, it may perhaps be concluded, that the emiſſion of heat and light is more copious in ordinary combuſtion than in the other caſes before us, only by the emiſſion of what was *further* combined as indiſpenſable articles of the gaſeous form in which oxygen and azote exiſt in the atmoſphere, that is, by the emiſſion of the latent heat of Dr. Black; a ſtate of the caloric different from that which requires a proper third ſubſtance, along with a high temperature, to diſengage it by ſuperior affinity.

But, although theſe conſiderations give a greater conſiſtency to the new doctrines, and leſſen ſome of their difficulties, the intelligent reader muſt, I think, perceive that the whole becomes hypothetical, and all the properties, affinities, and other relations of theſe ſuppoſed baſes of different kinds of gas, are mere interpretations of the phenomena; or rather are accommodations and corrections of ſuppoſed properties, till the hypotheſis is made to tally at laſt with all the phenomena. The hypotheſis ſeems to have nearly the ſame rank in ſcience with the magnetical hypotheſis of Æpinus. Both are ingenious and elegant, in the higheſt degree, and have ſuch a comprehenſive reſemblance to the phenomena, that the hypothetical principle becomes an excellent principle of arrangement or claſſification of the phenomena, almoſt equivalent to a juſt theory, and, in all probability, extremely near to it. Other caſes occur in the ſubſequent lecture which will bring this ſubject again before us.

[*Note* 18. *p.* 478.]

Dr. Black having only given the general concluſions which have been drawn by theſe eminent chemiſts concerning this very ſingular ſubſtance, it ſeems neceſſary to mention the chief and moſt ſimple facts by which theſe opinions are ſupported.

If we boil the prepared alkali, called the lixivium ſanguinis, or Pruſſian alkali, with a diluted ſulphuric acid, vapours come off which are extremely volatile. When the diſtillation is ſkilfully conducted, the firſt vapours are found much more volatile than water, and cannot be condenſed, unleſs water be mixed with them, or preſented to them in the receiver. This vapour has a ſtrong ſmell, not diſagreeable, and is extremely inflammable.

This ſubſtance contains the colouring principle, and the lixivium now poſſeſſes none. Its taſte is ſweetiſh and aſtringent. But as this watery ſolution of it unites with all alkaline ſubſtances, and with metallic oxyds, and may be detached from one of them by means of another, in the ſame manner as acids, it is conſidered, chemically, as an acid, and has been called the PRUSSIAN, or PRUSSIC ACID, and its compounds have been called PRUSSIATES. That compound called the lixivium ſanguinis, prepared, or Pruſſian alkali, &c. is the PRUSSIATE OF POTASH.

The pruſſic acid, prepared in the way juſt now mentioned, is but impure. Mr. Scheele procured it in the greateſt purity, by firſt forming of this impure acid a pruſſiate of mercury, and then putting ſome filings of iron into it and a ſmall quantity of ſulphuric acid. This inſtantly decompoſed the mercurial pruſſiate, and even greatly weakened the attraction of the Pruſſic acid for the iron, by the exceſs of ſulphuric acid. The mixture being now diſtilled with an extremely gentle heat, and the firſt vapours only preſerved, the reſult was a pruſſic acid perfectly pure. With this, or ſuch as this, all the experiments for aſcertaining its properties are tried.

It combines, as I have ſaid, with all the ſubſtances which combine with acids, with various degrees of elective attraction. Lime water digeſted on Pruſſian blue combines with this matter alone, without taking up any iron, as the ſolution of alkali does. It acquires a yellow or ſtraw colour, and no longer manifeſts its alkaline qualities. It does not affect the teſt paper. It has loſt its alkaline taſte, and its attraction for carbonic acid. This compound, called the *pruſſiate of lime*, is a much fitter teſt of the preſence of iron, than the lixivium ſanguinis, or *pruſſiate of potaſh*, becauſe it contains no iron.

The union of this colouring matter with the various baſes, is exceedingly weak; for every acid, even the carbonic, detaches it from them all. Nay, Scheele found that carbonic acid rendered blood incapable of imparting the colouring quality to the lixivium ſanguinis. But, as obſerved by Dr. Black, the addition of a ſmall quantity of iron, either pure or very ſlightly calcined, ſo fixes this acid in the lixivium ſanguinis, that it now reſiſts the action of any diluted acid. It is found, however, that ſtrong ſulphuric acid diſ-

ſolves the blue precipitate, and forms with it a brown liquor,—but it becomes blue by diluting with water.

Mr. Berthollet has greatly augmented our knowledge of the pruſſic acid diſcovered by Scheele. He found that in Scheele's decompoſition of the mercurial pruſſiate by means of iron, the iron took from it not only its pruſſic acid, but alſo its oxygen; for the iron was now an oxyd, and the mercury was revived.

His moſt curious obſervations related to the ſuper-oxygenation of the pruſſic acid. He found that when mixed with oxygenated muriatic acid, it reduced the muriatic to its ordinary ſtate, while the pruſſic had now acquired the abundant oxygen of the other, and its properties were greatly changed. It is now much more volatile, and if expoſed to the ſun's light, it acquires the ſmell of aromatic oil, and even collects into a fluggiſh oil like liquor, heavier than water, and it is no longer inflammable, nor precipitates iron. It is ſaturated with oxygen, which is equivalent to its being burnt already. In this oxygenated ſtate, it does not form a blue, but a green precipitate, with the ſolution of vitriol. This is not owing to the mixture of a really blue precipitate with yellow oxyd of iron; for muriatic acid does not diſſolve this oxyd, nor change the colour. It may be brought back from this ſtate by ſulphurous or volatile vitriolic acid. This is evidently by abſtraction of part of the oxygen by the ſulphurous acid. And, conformably with this account of it, we obſerve that the green precipitate mentioned juſt now, is made blue by the volatile vitriolic acid. The ſame effect is produced by expoſure to the light. Now we know that in all caſes of ſuper-oxygenation, light detaches the redundant oxygen.

Scheele's preparation of Pruſſian alkali by means of ſal ammoniac, chalk, alkali, and charcoal, ſhews that volatile alkali, or its component parts, hydrogen and azote, enter into the compoſition of the pruſſic acid. And if cauſtic fixed alkali or lime be mixed with oxygenated pruſſic acid, we have the vapours of cauſtic volatile alkali. Moreover, if the alkali or lime be now detached by ſulphuric acid, we do not obtain the pruſſic acid again: It has been deſtroyed; and the volatile alkali juſt now mentioned has been part of it. But further, this addition of ſulphuric acid produces effervescence of fixed air, or carbonic acid. This was not ſeen before. It would ſeem, therefore, that this is the other ingredient of the pruſſic acid, and that it conſiſts of volatile alkali and fixed air, or of their component parts, hydrogen, azote, carbon, and oxygen; perhaps the laſt does not exiſt in it, but is furniſhed by the water in the diſtillation of pruſſic acid, and in that proceſs combines with the carbon, forming the baſis of carbonic acid.

After all the inveſtigations of this eminent chemiſt, there is ſtill a great uncertainty as to the real ſtate of things in Pruſſian blue. I think that there may be ſtrong objections made to the exiſtence of any triple compounds in chemiſtry, and that all the examples offered are really mixtures of the third, with a true compound of the other two. Mr. Berthollet ſays, that there are two kinds of the pruſſiate of iron. One is the common Pruſſian blue, containing the iron or its oxyd, ſaturated with the tinging matter. The other conſiſts of oxyd not ſaturated, or precipitate of iron with exceſs of oxyd. We ob-

tain this by digeſting an alkali on Pruſſian blue. It evidently takes to itſelf part of the colouring matter. But the remainder is not, as commonly thought, an ordinary oxyd; for when an acid is poured on it, we obtain Pruſſian blue.

Alkali prepared in this manner, by digeſting on Pruſſian blue by the aſſiſtance of heat, contains a conſiderable quantity of the ſecond kind of precipitate. It will, by cooling for a conſiderable time, depoſit this in form of a yellow calx. When thus freed from it, evaporated to dryneſs, and then rediſſolved in water, it is called *purified Pruſſian alkali.* Mixture with vitriol produces no blue, if kept in the dark; but the light cauſes the blue precipitate to form gradually, till the whole alkali is decompounded.

[*Note* 19. *p.* 483.]

I forgot, when conſidering the ſolution of iron in the muriatic acid, to mention a curious obſervation of the Duke D'Ayen. When the martial muriat is expoſed to a mild heat, water only ſlightly acidulated is diſengaged,—then part of the acid riſes, in almoſt incoercible fumes, but pure,—then a compound of the iron and acid riſes, and condenſes in elegant lancet-ſhaped cryſtals. When the more fixed matter which remains is urged by the moſt violent heat, there riſes a vapour which ſeems truly metallic, condenſing in regular hexagonal cryſtals, having the full opacity and luſtre of poliſhed ſteel, and ſtrongly attracted by the loadſtone.

This is unqueſtionably a volatilization of the metal; and I think points out ſome cementing proceſſes, ſuch as with common ſalt, which ſhould make us expect valuable reſults. If this ſublimate be a pure iron, it is ſurely in a ſtate that we are not acquainted with. I ſhould wiſh that in this proceſs of the Duke D'Ayen, a magnet had been placed in the way of the vapours, or even applied externally by one of its poles, to the part of the receiver on which the ſublimate appears to accumulate moſt ſpeedily.

[*Note* 20. *p.* 492.]

Theſe two remarkable maſſes of malleable iron mentioned in the text have greatly puzzled the naturaliſts who have attempted to account for them. Both were found ſo far from all traces of habitation, that there is no ſuſpicion that they have been brought into that ſtate by the operation of man. And indeed the appearance of the Siberian maſs is ſuch as could not have been induced by our greateſt heats in our beſt furnaces. The whole has been in a ſtate of moſt violent ebullition, there being many bladders in it larger than an egg, and the ſurface is all bliſtered. The whole is covered with a cruſt like iron-ſtone, but internally, it is good red-ſhort malleable iron. The maſs found in South America is about fifteen tons weight, and of ſimilar ſtructure, but not ſo ſolid. This, and another of ſtill larger ſize, and branched like a ſtumped tree, found in the the ſame woods, three hundred miles from all appearances of iron, or even of ſtone, were

lying on the ſurface of the earth. (*Phil. Tranſ.* 1788.) A maſs of the ſame kind and appearance, near ſeven tons weight, was found under the pavement at Aken near Magdeburg, and is excellent iron.

In all thoſe inſtances, it is remarkable that the fuſion has been more complete than we can produce in our beſt furnaces. Alſo the glaſſy matter is tranſparent, and altogether unlike the ſlags which are formed in our metallurgic operations. No appearances of ſulphurous admixture are obſerved in thoſe maſſes.

Profeſſor Chladni, an author of great reſpectability, is much diſpoſed to think that all theſe maſſes have been portions of thoſe fire-balls which are often obſerved to move in our atmoſphere with immenſe velocity,—with a dazzling flaſhing light, frequently with ſmoke, making a ruſtling noiſe, and ſometimes burſting in pieces with a loud exploſion. The Siberian Tartars worſhip the lump above mentioned, as a thing come down from heaven. Many accounts have been given of red hot maſſes which have fallen through the air; and thoſe which have been ſhewn as ſuch are all of the ſame kind, conſiſting chiefly of malleable iron. Chladni gives a circumſtantial account of three. One example at Hraſchina, near Agram, in Hungary, is atteſted by many witneſſes, before the Biſhop's conſiſtory at Agram. It was ſeen coming from a great diſtance, with a brandiſhing unequal light, like a long flaming chain; and it ſplit into two pieces, which fell about a mile aſunder, making holes *more than an ell wide*, and three fathoms deep. One weighed ſeventy-one, and the other ſixteen pounds; and they are now in the Emperor's muſeum at Vienna. They are of the ſame kind exactly with thoſe already deſcribed. That ſuch triſling maſſes ſhould make ſuch excavations, can be accounted for, only by ſuppoſing them to be in a ſtate of continual exploſion or deflagration, blowing in all directions, like the inſtrument of deſtruction called a carcaſſe, diſcharged by a mortar. This will alſo give them a great apparent diameter while moving through the air. (*See Chladni's Diſſertation on the Maſs of Iron found in Siberia, Leipzig*, 1794; *and the Art of Mining and Metallurgy*, by Mr. Stultz, keeper of the mineral muſeum at Vienna, 1789. See alſo ſome valuable papers by Mr. Howard, in the Philoſophical Tranſactions, 1802, &c. or extracts from them in Nicholſon's Philoſophical Journal. In theſe papers every thing has been collected which has a relation to the ſubject; and Mr. Howard's obſervations are eminently ingenious and inſtructive.

[*Note* 21. *p.* 506.]

Dr. Black's notes contain no account of this proceſs. I believe that it is not generally known; and although Jars has publiſhed what he calls the proceſs carried on in Sheffield, we get little information from it. From the circumſtance that the ores which afford a metal nearly in the ſtate of ſteel, are generally ſpathoſe, or analogous to them, it ſeems not unlikely that the carbon which it wanted to form ſteel may be had in the fixed air.

Accordingly, many of the old proceſſes for caſe hardening iron, and for making little bits of ſteel, employ crude calcareous earth. The carburet (ſo plumbago is conſidered) burns very ſlowly. Perhaps even carbonic acid may be decompounded by iron, by the help of ſome double elective attraction; and the ſecret flux, of which Mr. Jars ſpeaks, may be a mixture containing limeſtone, and a proper reagent.

[*Note* 22. *p.* 522.]

I confeſs that this appears to me to be an inaccurate, or at leaſt an imperfect account of the matter. If indeed it relates only to the heat produced in the union of the nitrous and the vital air, to form nitrous acid, it is ſatisfactory: But if it be meant to explain the heat which is obſerved in the ſolution, when the gaſes are forming, it is ſurely inaccurate. Indeed this heat has always ſtruck me as a very great difficulty in the whole theory. Mr. Lavoiſier unqueſtionably derives his explanation of the heat produced in combuſtion from Dr. Black's theory of fluidity and vapour, and ſuppoſes that a gas conſiſts of its radical, or diſtinguiſhing ingredient, combined with calorique, according to the ordinary laws of chemical affinity. This being ſuppoſed, the ſolution of metal in an acid, ſo far from producing or extricating calorique, ſhould abſorb it from the materials, and produce a cold incomparably more intenſe than any of our freezing mixtures. For ſuch ſolutions, whether the metal be oxydated by the acid or the water, are always accompanied by the eruption of gaſeous fumes. Iron in the diluted ſulphuric acid produces an immenſe volume of gas. Thoſe metals which are oxydated by decompounding the acid, produce gaſes which ſtill contain much oxygen. And it may be remarked that, in general, thoſe ſolutions which produce fumes moſt deficient in oxygen produce the greateſt heats. This fact is favourable to Mr. Lavoiſier's explanation. The oxygen remaining in its concrete form, does not expend any of the calorique extricated by other circumſtances of the proceſs. Suppoſing that no more latent heat is neceſſary than for the production of as much watery vapour as ſhould have the ſame denſity, the quantity is very great, when compared with that which occaſions the cold in our freezing mixtures. It muſt not be ſaid that the quantity neceſſary for this gaſeous combination may be ſmall; for in this caſe, we ſhould often have gaſes inſtead of ordinary vapours, whereas, we know that an incomparably greater ſupply of calorique is required for the formation of a gas. Beſides, the Lavoiſierian theory of combuſtion ſuppoſes a vaſt accumulation of heat in oxygenous gas; this being, according to that celebrated philoſopher, the ſource of all the heat extricated in that operation of nature. It muſt alſo be obſerved here, that the oxygenous gas gives out this heat, and the oxygen is combined with the inflammable body, in a ſtate very ſimilar to its condition in the preſent experiment. Therefore, we unqueſtionably have a prodigious quantity to account for, the oxygen in the diſſolving or combining ſubſtances being unprovided in the quantity neceſſary for its becoming a ſource of heat in ſome future combuſtion.

I would now aſk in what ſtate is the calorique contained in the materials of an acid and a metal, when they act on each other? Some of the materials muſt contain it in a ſtate that is unneceſſary for their appearance in the ſtate of a ſolution, of an oxyd, or of a metalline ſalt. When all this calorique has emerged, the oxygen in nitre ſtill contains a great ſtore of it, ſeeing that it is extricated from it in deflagration with inflammable ſubſtances. This only increaſes the difficulty. For this great ſtore of calorique muſt remain in the ſolution, and in the metallic ſalt which it produces. Heat is extricated in the ſolution, and gas containing oxygen is produced. This gas, by uniting with vital air, again detaches calorique, and produces nitric acid. This acid will diſſolve metal, and again detach calorique. This may be continued without end. This circumſtance alone ſhould convince us that there is ſome error in our theory, becauſe this endleſs generation of heat is impoſſible in the nature of things. We cannot ſay, with any well grounded confidence, whether more calorique is extricated from oxygen, when, in the gaſeous form, it cauſes the combuſtion of ſulphur, or when, as an ingredient of nitre, it contributes to the deflagration with the ſame ſulphur. I grant that I think that more is extricated in the firſt caſe. But it ſhould be an immenſe deal more. For methods may be found for transferring the oxygen of the ſulphuric acid, formed in the firſt caſe, to azote, and of thus forming nitric acid, and nitre, which will again deflagrate with ſulphur.

All this is myſterious and intricate. I do not ſay incompatible; but I am not able to reconcile them by means of any known facts. The ſame, or greater difficulties, occur in almoſt all the ſpontaneous inflammations; in the deflagrations of nitrous acid with eſſential oils, and in many detonations; and in particular the heat and light which we call glow, or incandeſcence;—eſpecially ſuch as appears in the Dutch experiments, mentioned in page 642, on the mixture of ſulphur with ſeveral metals. I acknowledge that I never was ſatisfied with the explanations given of this ſubject. Indeed it is rather kept out of ſight by the French chemiſts. I am informed that Mr. Meunier, who was one of Mr. Lavoiſier's chief aſſiſtants, tried many experiments, in company with Dr. Sommering of Mentz, and that they communicated their obſervations with Lavoiſier and the chemiſts of Paris, and that theſe gentlemen were ſo little pleaſed with the reſults, that they were never mentioned in the Academy. I am diſpoſed to aſſign a very different ſource of the heat in all theſe operations; and ſhould this work have a ſecond edition, I may probably have ſo far matured my notions on the ſubject as to think them not unworthy of the public attention. At preſent they are by no means in ſuch a ſtate.

[*Note* 23. *p.* 528.]

The very ingenious Mr. Davy, chemical lecturer in the Royal Inſtitution in London, has publiſhed, in *Nicholſon's Philoſophical Journal, vol. III. p.* 515. *and vol. V. p.* 281. the

outlines of a chemical examination of this gas, which he very properly denominates Nitrous Oxyd. He there mentions, in very general terms, its relations to heat, water, acids, alkalis, inflammable ſubſtances, &c. the methods of producing it, deduced from a due conſideration of thoſe relations, and the appearances of its compounds. This ſketch is the performance of a ſagacious obſerver and good reaſoner.

With regard to its production, his experiments confirm Dr. Black's conjecture very clearly. He ſays that the moſt uniform and expeditious method of changing nitrous air into nitrous oxyd is to expoſe it to the action of a ſulphite of potaſh or ſoda. In an hour's time, 100 grains of dry ſulphite of potaſh converts 16 cubic inches of nitrous air into eight inches of nitrous oxyd, and is itſelf partly changed into an ordinary ſulphat.

But the method of preparing this oxyd, which he found the moſt convenient of all, was by means of nitrous ammoniac, mixed with thrice its weight of ſand. This ſalt, the *nitrum flammans* of the older chemiſts, notwithſtanding the ſingularity of its moſt obvious properties, has ſomehow eſcaped the pertinacious ſcrutiny of the chemiſts for a long while. Mr. Davy has made ſome very judicious experiments on it, and obſerved properties which are undoubtedly of great value, by the information they ſeem to give concerning the changes made on the affinities of chemical ſubſtances by a change of temperature. If nitrous ammoniac be kept ſteadily in a temperature very little exceeding 320 of Fahrenheit, it melts, and decompoſes completely, reſolving itſelf into water and the gas now under conſideration. If raiſed much above 400°, and approaching to 500°, the conſtituent ſubſtances take other combinations, and produce the ordinary nitrous gas, and azotic gas, not combined. Probably, a very nice management of the heat might determine it either to the one or the other of thoſe products, along with the water, which ſeems to form in every temperature, once the ſalt has melted. Should the temperature riſe to 700°, another combination takes place, and the oxygenous gas is decompoſed, and we have a detonation. It muſt be remarked that the formation of nitrous gas and azotic gas is accompanied by a luminous appearance in the veſſels. This is probably analogous to the low inflammation of phoſphorus, ſulphur, and other inflammable ſubſtances, and ſhould induce us to examine thoſe phenomena, to ſee whether they alſo are accompanied by ſuch a change in their gaſeous productions.

This is ſaid to be the proceſs employed by the ſociety of chemiſts who have lately attracted ſo much notice by the employment of this gas for medicinal and dietetical purpoſes. Its effects, when breathed for ſome time, are very wonderful, and were firſt diſcovered, I believe, by Mr. Davy. To thoſe who are not hurt by the ſight of folly, they are alſo very amuſing.

Mr. Davy has alſo very ingeniouſly combined this gas with alkalis. He triturates a dry cauſtic alkali with a ſulphite, and expoſes the mixture to the action of nitrous gas. In this way the alkali acts on the nitrous oxyd, ſo as to combine with it in the very inſtant of its formation. He had found that the oxyd, already in a gaſeous ſtate, con-

tracts no union with alkalis, if dry, and ſcarcely if in a watery ſolution. The compound taſted almoſt like a cauſtic alkali, but with a very peculiar pungency. The oxyd is expelled, in its genuine form, by any acid; alſo by a temperature exceeding 400°.

Inflammable ſubſtances decompound nitrous oxyd, much in the ſame way that they decompound nitrous acid, but the decompoſition requires a much higher temperature. Sulphur burning ſlowly, with its weak blue flame, is extinguiſhed in it. So are charcoal and phoſphorus, if in their loweſt temperature of combuſtion. But if any of thoſe ſubſtances be made to burn briſkly, producing a white light, they decompound nitrous oxyd with great rapidity, with an enlarged flame, and even deflagration. Therefore a candle burns with an enlarged flame, having a beautiful roſe-coloured light. The ſulphurous pyrophori burn vividly, but require a conſiderable heat to begin the combuſtion.

There is a peculiarity attending the burning in this gas. Nitrous acid is produced. Mr. Davy imagines that this ariſes from a new arrangement of principles, occaſioned by the ignition of a *part* of the gas that is not immediately contiguous to the flame. He explains in the ſame way, ſome other phenomena which diſtinguiſh this gas from nitrous acid.

By comparing a variety of appearances Mr. Davy concludes, that 100 parts of this oxyd conſiſt of thirty ſeven-parts of oxygen, and ſixty-three of azote, in a much denſer ſtate than that of their ſeparate exiſtence.

[*Note* 24. *p.* 545.]

Mr. Howard has communicated to the Royal Society of London a very curious account of a preparation of mercury, which explodes by a ſpark or an electrical ſhock, in the ſame way as gunpowder, but with incomparably greater force, and with ſome peculiarities, which are remarkable and inſtructive. (*See Phil. Tranſ.* 1800. *p.* 204.)

The red oxyd of mercury was mixed with alcohol, and nitric acid was poured on it. It diſſolved the oxyd before it acted remarkably on the alcohol; and after ſome time there was an ebullition, which ſent forth a denſe white ſmoke, ſmelling ſtrongly of æther. The mixture depoſited a precipitate, at firſt of a dark brown, and it gradually grew whiter. When ſeparated by filtration, it appeared cryſtallized. Sulphuric acid was poured on this ſaline maſs. A violent effervescence enſued, and the mixture exploded. When the ſulphuric acid was much concentrated, the exploſion often happened at the firſt contact.

Three or four grains of this ſalt in dry powder were laid on an anvil, and were ſtruck with a ſmart blow with a hammer, in the manner practiſed by Fourcroy and Vauquelin with ſeveral ſalts. It detonated with great violence, and the faces of the anvil and hammer were very ſenſibly indented. The ſame effects were produced by ſending the ſhock of an electrical battery through five or ſix grains of it. The report of two grains is always as loud as that of a muſket.

Two or three grains, lying in a ſort of cup of tin-foil, were thus made to float on ſome oil. This was heated gradually; and the powder exploded when the temperature roſe to 368°.

Mr. Howard then examined the exploſive or expanſive power of this ſubſtance when fired in the chamber of a piece, in the manner of gunpowder. It burſt the barrel in which it was fired in a very extraordinary manner. Seventeen grains of it, however, were fired in the chamber of a fowling-piece, without deſtroying it. There was no recoil that was remarkable. The report was feeble; and the ball had about half the force which an ordinary charge, or 68 grains of the beſt gunpowder, would have given it. When the experiment was repeated with 34 grains, the barrel was deſtroyed, being torn into many pieces at the breech.

The expanſive power of this ſubſtance was compared with that of gunpowder, by firing half an ounce of each in two chambers, bored with the ſame tool, in two blocks of hard wood. The gunpowder ſplit the block into three pieces, driving them from each other till the flame had room to eſcape. The mercurial powder burſt its block in many directions, but without ſenſibly ſeparating the fragments;—the parts adjoining to the powder were pounded to duſt.

A box of caſt iron was made to fit exactly the chamber of a twelve-pound carronade. It had a cavity which held three and a half ounces of the mercurial powder. The box conſiſted of two parts, firmly ſcrewed together. It was put into the carronade, and three twelve-pound balls were put above it. The powder was fired through a ſmall touch-hole. The fore part of the box was blown out. The other part was ſhivered into many pieces; ſo were the two undermoſt balls; and the uppermoſt was cracked through the centre. The report was extremely feeble. The entire ball ſtruck the mark with very little force.

Ten grains of the mercurial powder were fired by an electrical ſhock, in the centre of a glaſs ball ſeven inches in diameter, and half an inch thick. The glaſs withſtood the ſhock; and its inſide was coated with metallic mercury. Only four cubical inches of gas were found added to the air in the glaſs. They were a mixture of azote and carbonic acid. Ten grains of gunpowder were fired in the ſame manner, but no meaſure was taken of the gas. Indeed little could be inferred from the gaſes remaining when all is cold, becauſe we are ignorant of what is abſorbed. What is moſt remarkable in this experiment is, that the inflammation which takes place in this exploſion, will not inflame gunpowder mixed with it in a looſe ſtate.

Mr. Howard aſcribes the great force of the exploſion to a greater rapidity of inflammation. He might have added, in all probability, a more complete inflammation; for ſome grains of the gunpowder were not inflamed. Indeed there is uſually a very great portion that is driven out of the way without inflaming, when the powder lies looſe, as in this caſe it did.

The moſt important circumſtance in the experiment is the rapid diminution of the

expanſive force by an enlargement of bulk; it ſeems irreſiſtible, while the particles of the gas are very near each other, but moderate, as ſoon as they have receded to a ſmall diſtance. The effects of gunpowder agree very well with the ſuppoſition of a repulſive force between the particles, and acting only on the immediately adjoining particles, inverſely proportional to their diſtance. The repulſion of the particles of this mercuriated gas muſt decreaſe much faſter, and may perhaps be as the ſquare of the diſtance inverſely. But be it what it will, it has a different law, and therefore is a different gas from that of gunpowder, perhaps containing the vapour of mercury itſelf. There are experiments, by which it appears that this vapour is indeed very expanſive. It may alſo have very little latent heat.

This diſſertation is full of the moſt acute obſervations; and contains a moſt ingenious analyſis of the phenomena, and much chemical ſcience.

[*Note* 25. *p.* 544.]

As this is the firſt example which we have, in Dr. Black's arrangement of the metals, of the ſeparation of one metal by another, it may not be improper to pay a little more attention to the general phenomena.

The firſt obſervation I have to make on it is, that there is not that violent effervеſcence accompanying the ſolution of the added metal, as when that metal is put into the pure acid. In ſome caſes there is no effervеſcence whatever, and in every caſe the effervеſcence is extremely ſlight.

I may alſo obſerve, that the preſent example, the precipitation of mercury by copper, is the firſt fact appealed to by Dr. Stahl, as a ſtrong argument for his doctrine of phlogiſton. He appeals to it as a thing long and well known. There are many others equally diſtinct. Thus, lead diſſolved by acetous acid is precipitated by zinc, in fine metalline cryſtals, like ſugar candy. Silver is precipitated from the nitrous acid by copper, alſo in metalline cryſtals. This precipitation forms a very beautiful object, when viewed through a microſcope, as it goes on in a drop of the ſolution, when a particle of copper is placed in contact with it. The cryſtals will be ſeen ſtarting, as it were, into exiſtence, or ſhooting out in fine ramifications.

According to the doctrine of Stahl, when a metal is diſſolved in an acid, the acid is ſuppoſed to unite with the calx and expel the phlogiſton. Therefore, when an alkali is thrown into the ſolution, the precipitate muſt be conceived to be a calx, perhaps combined with a portion of the acid, or the alkali, or both. But when one metal is employed to precipitate the calx of another, the ſeparation muſt be aſcribed to the ſuperior attraction of the acid for the calx of the added metal. For when this metal is diſſolved in the pure acid, its phlogiſton is ſuppoſed to eſcape. To abide by the example in the text, the acid muſt be ſuppoſed to have a ſtronger attraction for the calx of copper than for that of mer-

cury. Therefore, when mercury is thus ſeparated by copper, the phlogiſton of the copper muſt be ſuppoſed to be expelled from the calx. It does not quit the mixture, but unites with the precipitated calx of mercury, and changes it into a metal.

Dr. Stahl accordingly aſſerted this double exchange, and ſays that it is confirmed by the want of effervescence in moſt caſes, and by the very faint effervescence in all. This ſmall effervescence he accounts for in a manner ſufficiently ſatisfactory, by ſaying that the precipitated metal did not require for its metallic form all the phlogiſton which the acid expelled from the other.

Dr. Black, while he acquieſced in the doctrine of Stahl, did not content himſelf with a mere expreſſion of this acquieſcence, but was accuſtomed to exhibit this doctrine as not only plauſible, but as extremely ingenious and elegant; and was at ſome pains to obviate the objections which were made to it. He ſaw clearly that it claſhed with no principles of philoſophy, to ſay that a ſubſtance might be poſitively light; and when I reminded him of the experiments on pendulums, by which Sir Iſaac Newton proved that all ſublunary matter is *equally* heavy, he conſidered theſe experiments with care, and thought that they were not ſuſceptible of the accuracy neceſſary for deciding the queſtion; becauſe he obſerved that the exact determination of the centre of oſcillation of ſuch pendulums as Newton muſt have employed, was a thing which could ſcarcely be accompliſhed. It was this objection by Dr. Black which made me repeat Newton's experiments, in a form where the poſition of the centre of oſcillation is of no conſequence. *(See Encycl. Britan. Supp. § Aſtronomy.)*

Impreſſed with this favourable notion of the doctrine of Stahl, Dr. Black was much offended by the contemptuous terms in which more than one or two French chemiſts ſpoke of it,—calling it diſgraceful to ſcience, and what no man of common ſenſe could adopt for a minute. He thought Stahl, Margraaf, Cramer, and other German chemiſts, by no means deficient in common ſenſe; and uſed to ſay, that the French chemiſts forgot, in their daſhing leſſons to the reſt of Europe, that Macquer, Geoffroi, Beaumé, were their countrymen. No man had a higher opinion of the genius, penetration, and ſagacity of Mr. Lavoiſier, than Dr. Black; and I have often heard him lament the loſs which ſcience ſuſtained by his death. He admired particularly Lavoiſier's quick ſight of the importance of Mr. Cavendiſh's diſcovery of the compoſition of water, and his employing it immediately, not only to get over the difficulties which all the acids, except the nitrous, brought into view, but even to extend his doctrine far beyond the firſt conceptions of it. Dr. Black adopted all Lavoiſier's doctrines, but he did not like the officious (as he called it) interference of ſome of his coadjutors; and he ſaid that Berthollet was the only one of them in whoſe judgment and caution he had full confidence. With all this candour, he never would allow Stahl's doctrine to be ſpoken of in a ſlighting manner.

But to return from this eulogy on Stahl:—We muſt examine the manner in which the ſeparation of one metal by means of another is explained in the doctrine of the French chemiſts. It is extremely eaſy, and pretty ſatisfactory, but it requires a little more

thought and reflection to underſtand the whole internal procedure; and there are ſome caſes in which there are difficulties which I do not think eaſily ſurmounted.

What is called the ſolution of a metal in an acid is, in general, rather the ſolution of a metallic oxyd, and we muſt regard this ſolution and the previous oxydation as two ſeparate operations. When a metal is firſt oxydated, and then diſſolved in an acid, we do not ſee where the one operation terminates, and the other begins; the one operation ſeems juſt the continuation of the other. If we attempt to reſolve theſe queſtions by having recourſe to attractions and repulſions, and to conceive this ſucceſſion of changes in a mechanical way, as is done by many who would be thought philoſophical chemiſts, we ſhall find ourſelves immediately put to a ſtand. For in mechaniſm, the law of continuity ſuffers no exceptions. But chemiſtry itſelf helps our conceptions of this matter, by ſhewing us other caſes, where a ſimilar ſucceſſion of phenomena appears. Thus, the continued addition of heat to a ſubſtance ſhews us firſt the ſolid,—then a fluid,—then a vapour. And in each of theſe changes of conſtitution and properties, there is a great abſorption of heat. We have another example ſtill more analogous. By gradually evaporating any brine, we at laſt produce cryſtals of ſalt, ſtill conſiſting of the ſaline matter combined with water. Here the formation of a ſaline cryſtal, by the pure ſalt *firſt* attaching to itſelf the water of cryſtallization, which it certainly will do, if no more water be ſupplied to it, and then its ſubſequent ſolution in more water, are facts which very much reſemble the formation of an oxyd, and its ſubſequent ſolution in more acid. Careful obſervation may diſcover many more examples of ſuch a ſeries, and it may be known as a very common phenomenon,—as a general though not univerſal law. But this is all the explanation that pure chemiſtry affords; and it is by a judicious obſervation and employment of ſuch general laws, that it has become ſo comprehenſive and important a department of natural knowledge.

Being more familiarly acquainted with the cryſtalline and briny forms of a ſalt, we ſeem a little entitled to reaſon from theſe to ſimilar ſubjects which are leſs intimately known; and we are led to believe, that the oxygen which forms part of the oxyd, is more firmly united with the mercury, than what is afterwards combined with it as an ingredient of the acid. And this opinion is confirmed by obſerving, that in moſt caſes, we can eaſily detach the acid, but that it is very difficult to detach the pure oxygen. In many caſes, the moſt intenſe heat will not detach this laſt. Alſo, although we do not in the leaſt underſtand why or how the previous union of the oxygen with the azote of the nitrous acid ſhould make its diſpoſition to combine with the mercury any leſs, we know that this is a general fact in chemiſtry. And laſtly, though ignorant of the efficient reaſon, we know that in proportion as more of an ingredient is already united with another, all ſubſequent additions are made with leſs force, and the union is leſs firm, or more eaſily deſtroyed.

Having theſe notions of the affinities of ſubſtances, we muſt ſuppoſe that the copper firſt attaches to itſelf as much oxygen as will render it an oxyd ſuſceptible of union with

the nitrous acid. This muſt certainly be taken from the mercurial nitrate, leaving the mercury ſtill in the ſtate of oxyd. It muſt therefore be taken from the nitrous acid in the mixture. This muſt be the order of procedure, becauſe it is this portion of the oxygen that is eaſieſt detached. The acid is already in the form of *nitrous* acid, having been decompoſed in part when diſſolving the mercury. Or, if we allow the acid of ſolution to be nitric acid, the firſt effect of the copper muſt ſtill be to decompoſe ſome acid. The copper oxyd is at length formed, and now diſſolves, by abſtracting, not oxygen, but nitrous or nitric acid from the nitrate. This it continues to do more and more, reducing the mercury to the ſtate of an oxyd, and laſt of all leaving it in its primitive form of a metal. This order of procedure is confirmed by obſerving, that in ſome caſes the metal is left in the ſtate of an oxyd, or in a ſtate very little removed from it.

Now this procedure has, I think, conſiderable difficulties. We do not ſee, in any caſe, how the affinity of the copper for acid or oxygen, which continually diminiſhes as it attaches more to itſelf, is at laſt able to deprive the mercury of that portion of oxygen that is moſt ſtrongly attached to it. We cannot ſuppoſe the oxydation of the mercury to be the firſt thing effected, being already perſuaded that the copper, which can decompoſe pure acid, will more readily decompoſe it, when the combination of the parts of the acid is weakened by its union with the mercurial oxyd. It muſt therefore take the oxygen from the acid, and not from the oxyd; and the mercurial oxyd muſt be the laſt thing decompoſed. The firmeſt combination muſt be overcome by the ſmalleſt force.

Nor is it without its difficulties, to conceive how a metal becomes ſoluble in an acid, only by being already combined with one of its ingredients. I do not know any ſimilar fact,—and I have little confidence in any other mode of chemical inveſtigation, and leaſt of all in reaſonings depending on the conſideration of attractions and repulſions.

Farther, if the copper is oxydated by decompoſing the nitric acid, we ſhould have an effervеſcence of nitrous air as ſtrong as when copper is put into pure acid. We cannot ſuppoſe that the redundant azote unites with the oxygen of the oxyd, and changes it into nitric or nitrous acid, becauſe the mercury was oxydated by means of an affinity for oxygen, ſtronger than that of azote for the ſame oxygen. I think that this effervеſcence ſhould be obſerved in every inſtance of ſeparating one metal by means of another; even when the added metal is oxydated by decompoſing the water. For I do not think that the redundant hydrogen will unite with the oxygen of the oxyd. Now theſe phenomena are not obſerved,—what effervеſcence is obſerved is always weak. We have not inflammable air in all the caſes where the added metal decompoſes the water. In ſuch caſes we are led to think that the hydrogen is expended during the decompoſition of the oxyd of the diſſolved metal. But this alſo obliges us to ſuppoſe that the decompoſition of one oxyd, and the formation of the other, are the firſt parts of the whole proceſs, a thing which does not agree with our notions of the affinities.

I do not think it will be difficult to decide theſe queſtions by proper experiments, but none ſuch have yet come in my way.

[*Note* 26. *p.* 553.]

As the notes found among Dr. Black's papers are not in ſuch a condition that I can lay them before the reader, ſo as to anſwer the purpoſes mentioned in the lecture, I muſt content myſelf with giving the chemical arrangement of the medicinal preparations of mercury that was followed by him in his diſcourſes, with ſuch of his obſervations on particular medicines as I thought might be of uſe.

Table of the Preparations of Mercury, as drawn out by Dr. Black.

Hydrargyrus praeparatur ad Uſus Medicos.

I. Deſtillatione, ut purus fiat.

Hydrargyrus purificatus. Lond.

II. Triturâ, ut in atomos inviſibiles attenuetur.

Merc. gummoſ. Plenckii.
Pilulae Hydrargyri. Ed. et Lond.
Hydrargyrus cum cretâ. Lond.
Emplaſtrum Hydrargyri, ſive coerul. Ed.
Emplaſtrum Lithargyri cum Hydrargyro. Lond.
Emplaſtrum Ammoniaci cum Hydrargyro. Lond.
Unguentum Hydrargyri, ſive coerul. Ed.
Unguentum Hydrargyri fortius et mitius. Lond.

III. Calcinatione Ignis Ope et Aëris.

Hydrargyrus calcinatus. Lond.
Olim Mercurius praecipitatus per ſe.

IV. Viribus Salium.

1. Cum Acido Vitriolico.

Hydrargyrus vitriolatus flavus, vulgo Turpethum minerale. Ed.
Hydrargyrus vitriolatus. Lond.

2. Cum Acido Nitroſo.

Guttae albae Wardi. *(a)*

(a) Dr. Black has given the following account of the proceſs for preparing this medicine, known by the name of *Ward's white drop*:

Unguentum Hydrargyri nitrati. Ed. et Lond. *(b)*
Hydrargyrus nitratus ruber. Ed. et Lond.

3. Cum Acido Muriatico.

Hydrargyrus muriatus corrosivus. Ed.
Hydrargyrus Muriatus. Lond.
Hydrargyrus Muriatus mitis. Ed.
Calomelas. Lond.
Hydrargyrus Muriatus praecipitatus. Ed. } *(c)*
Hydrargyrus Muriatus mitis. Lond. }

4. Cum Acido Acetoso.

Hydrargyrus Acetatus. Ed. et Lond.
Pilulae Keyseri. (d)

A mixture being made of sixteen parts of pure aquafortis, and seven of volatile sal ammoniac, four parts of mercury are added for every sixteen of the mixture; and the mercury being dissolved, as much more is added as the liquor will dissolve.

This is evaporated till a pellicle just appears on the surface. It is now allowed to cool. When cold, the heavy, uncrystallized, or fluid part, is drained off. The crystallized salt is dissolved in thrice its weight of rose water, which forms the white drop. The dose is in two drops, each dose containing half a grain of mercury.

(b) A variety of this ointment is used with success in the Manchester infirmary. It is prepared with the oil of butter, which has had no salt whatever. This preparation is found to preserve its colour unchanged.

(c) Dr. Black has written, on a copy of this table, an account of Scheele's process for this medicine, *viâ humidâ*, as follows:

Half a pound of mercury, and as much aquafortis, are put into a small matrass or cucurbit, having a pretty long neck. The mouth of it being covered with a bit of paper, a digesting sand-heat is given to the mixture for some hours. When the action of the acid becomes languid, the heat must be increased to nearly a boiling heat, and continued three or four hours,—agitating the mixture from time to time. At last, make the solution boil gently, for a quarter of an hour; at the end of which there should remain a small quantity of mercury undissolved.

While the above is going on, dissolve four and a half ounces of pure sea salt, in six or eight pounds of water. Mix this solution, boiling hot, with the solution of mercury, also boiling,—stirring violently while they are mixed. Then allow the precipitate to settle; and afterwards edulcorate it with repeated washings of hot water,—and dry it. We obtain a *mercurius dulcis* in impalpable powder, amounting to eight and a half ounces.

The efficacy of this process is explained by Dr. Black, on the principles advanced in the lecture, namely, that the solution of mercury, made as here directed, is a sort of compound solution, containing a quantity of the metal, not oxydated, sufficient completely to saturate the muriatic acid. In proof of which, he says that this solution is precipitated black (a mark of crude mercury) by an alkali; whereas if the solution has been continued only till the cessation of effervescence, an alkali occasions a yellow precipitate, &c.

(d) Dr. Black refers for the preparation of this medicine to *Observ. de Medicine, de Mr. Richard, au Louvre*, 1772; and to the *Encyclopedie*.

5. Deturbatione ex Acidis vi Alkalinorum.

Hydrargyrus praecipitatus cinereus. Ed. } (e)
Mercurius praecipitatus fuſcus.

Calx Hydrargyri alba. Lond. (f)
Unguent. Calcis Hydrargyri albae. Lond.

V. Conjunctione cum Sulphure.

Hydrargyrus Sulphuratus niger. Ed.
Hydrargyrus cum Sulphure. Lond.
Hydrargyrus Sulphuratus ruber. Lond.
Pilulae Hydrargyri muriati mitis, ſive Calomelanos, compoſitae. Ed.

[*Note* 27. *p.* 563.]

Medicamenta parantur ex Antimonio, vel Sulphurato, vel Sulphure privato.

Ex Antimonio Sulphurato.

I. Triturâ.

Antimonium praeparatum. Ed. et Lond.

II. Ope Ignis et Aëris.

Flores Antimonii ſine addito.
Vitrum Antimonii. Ed.
Antimonium vitrificatum. Lond.
Vitrum Antimonii ceratum. Ed.

III. Vi Salis Alkalini.

Hepar Antimonii mitiſſimum.
Regulus Antimonii medicinalis.
Hepar ad Kermes minerale *Geoffroii.*

(e) This, as prepared in the ſhops, is ſaid to be frequently very acrimonious, which Dr. Black aſcribes to impure aquafortis in the preparation.

(f) This white precipitate may be made exactly ſimilar to calomel, by uſing plenty of volatile alkali for the precipitation, ſo much that the mixture may ſmell of it. This alkali will take from the metal a conſiderable quantity of the muriatic acid. Alſo by its hydrogen it deprives the quickſilver of the oxygen with which it was combined. The precipitate is therefore rendered inſoluble in water, and ſcarcely ſoluble in vegetable acids. It will be very different if we are ſparing of the alkali.

Dr. Black remarks in this note, that the foſſil alkali, though aërated, cannot be made to precipitate mercury from a ſolution of corroſive ſublimate, of a white colour, becauſe the quantity of it which is ſufficient for ſaturating the acid does not contain enough of air to ſaturate the mercurial precipitate, and render it white. He confirms this explanation by numbers, ſtating according to Mr. Kirwan's experiments, the quantity neceſſary for this purpoſe.

Hepar ad Tincturam Antimonii.
Kermes Minerale.
Sulphur Antimonii praecipitatum. Ed. et Lond.

IV. Vi Nitri Salis.

Crocus Antimonii mitiſſimus.
Vulgo Regulus Antimonii medicinalis.
Crocus Antimonii. Ed. et Lond.
Antimonii emeticum mitius. *Boerh.*
Antimonium uſtum cum Nitro, *vulgo* Calx Antimonii Nitrata. Ed.
Antimonium calcinatum. Lond. *Vulgo diaphoret.*
Antimonium Calcareo-phoſphoratum, ſive Pulvis antimonialis. Ed.
Pulvis Antimonialis. Lond.

V. Viribus Acidorum.

Antimonium vitriolatum. *Klaunig.*
Antimonium catharticum. *Wilſon.*
Antimonium muriatum, vulgo Butyrum Antim. Ed.
Antimonium Muriatum. Lond.
Pulvis Algerothi, ſive *Mercurius Vitae.*
Bezoardicum minerale.
Antimonium tartariſatum, vulgo Tartarus emeticus. Ed.
Antimonium Tartariſatum. Lond.
Vinum Antimonii tartariſati. Ed. et Lond.
Vinum Antimonii. Lond.

Ex Antimonio Sulphure privato.

Hoc Metallum, prout diverſis modis liberatur a Sulphure, dicitur Regulus Antimonii ſimplex, Regulus Antimonii Martialis, Regulus Jovialis, &c. Ex eo parata ſunt;

I. Ignis Vi et Aëris.

Flores Argentei, ſive Nix Antimonii.

II. Vi Nitri Salis.

Certiſſa Antimonii.
Stomachicum. *Poterii.*
Antihecticum. *Poterii.*
Cardiacum. *Poterii.*

Medicamenta ab Antimonio nomen mutuantia, quae tamen ejus Metalli vix quicquam retineat.

Cinabaris Antimonii.
Tinctura Antimonii.

[*Note* 28. *p.* 604.]

The grains of ſmall ſhot made in this way are very often hollow, or have a deep pit in one ſide, which is frequently rugged within. It is owing to the ſudden congelation of the outſide by the water. This forms a hard caſe, while the interior is ſtill fluid, and contracting as it cools, a part is left empty. As this greatly hurts the value of the ſmall ſhot, many attempts have been made to prevent it, which have been more or leſs ſucceſsful. Some manufacturers have mixed other metals with the lead,—others have kept oil on the water,—others receive the lead into boiling hot water covered with melted tallow. I believe that the moſt ſucceſsful method has been that of the patent ſhot manufacture in Southwark, London, where the furnace is at the top of a very high tower, not leſs than one hundred feet, and the ſhot is gradually cooled as it falls through the air. The chief effect of this, however, muſt be the incomparably greater number of ſpherical grains. I do not ſee how this will much prevent the hollowneſs of the ſhot, even although the tower were four times as high. The ſhot would fall two hundred and fifty feet in four ſeconds, and four hundred feet in five ſeconds, neither of which would ſufficiently cool the ſhot. Its latent heat requires a much longer time than this for its abſorption by air. The pear-like ſhape is occaſioned by the fluid lead within breaking through the cruſt, and freezing as it comes in contact with the water. Metals afford very curious forms, by dropping them when fluid into water. When this is done from a very ſmall height, the drops deſcend ſlowly through the water. The fluid within breaking the cruſt by its great weight, runs out, freezing as it goes down, and often leaves a pretty round thin cup with a taper thing below it like an extinguiſher. Some metals thus form themſelves into nails with large heads,—others take other ſhapes, very uniform, and very unexpected. Great differences are produced by different liquors inſtead of water, and by different heats of the metals, and by the heights from which they are poured, &c.

[*Note* 29. *p.* 639.]

It is by no means clear that the acid has increaſed its proportion of oxygen by deoxygenating the copper. It is true that the copper remaining in the retort ſcarcely needs any addition of inflammable matter to reduce it; but there is adhering to it a large proportion of extractive coaly matter, which anſwers the ſame purpoſe; and the fact is, that when this is urged by a ſtrong heat, we obtain a great deal of fixed air. Of this I have had repeated experience. It is indifferent whether this be conceived as compoſed of the oxygen of the cupreous oxyd or from the acid. In neither caſe can the acid be ſaid to have increaſed its proportion of oxygen in any other way than by leaving behind a portion of carbon. I ſee nothing that induces me to think even this to be the caſe, or that there is not as

much oxygen taken from the acid in this operation as belongs to the extractive or carbonic matter. Mr. Chaptal (*Ann. de Chymie*, vol. 28.) thinks that he ſees plain differences between what he chooſes to call acetous and acetic acid. But they appear to me very unſatisfactory. The ſuperior acidity of the acid obtained by the preſent proceſs is ſufficiently accounted for by its dephlegmation and freedom from mucilaginous and other extractive matter. At any rate, this is by no means the moſt eligible proceſs for obtaining from this ſalt the greateſt quantity of acetous or acetic acid, free from empyreuma; and, as Dr. Black has not mentioned any of the other methods of decompounding it, I truſt that the reader will not be diſpleaſed with ſome account of the moſt approved of them.

The ſimpleſt and moſt obvious of all is to employ the ſuperior affinity of another acid, and of theſe the moſt fixed is to be preferred. Concentrated ſulphuric acid being poured on the acetite of copper, it detaches the acid with great facility, and as agreeably fragrant as the *beſt* of the dry proceſs, or what comes over after the portion tinged with the copper, and before any empyreuma can be obſerved. It is alſo extremely ſtrong, and of a pungent odour, and the laſt portion is inflammable. This was firſt obſerved, I think, by Count de Lauragais; and he employed it to form an acetic æther, which exceeds others in fragrance. There is generally ſome carbonated matter left adhering to the ſulphat; and this has been adduced as a proof that the acetic acid, by depoſiting carbon, has become redundant in oxygen.

It will be ſaid that the acid obtained by this proceſs is not in a ſtate of complete dephlegmation, as in the other. But I may obſerve here, that the other proceſs cannot be eaſily conducted without ſome water. Without this addition, in order to tranſmit the heat more readily to the centre of the maſs, the acid cannot be expelled from thence, without over-heating the exterior parts.

A ſtill better proceſs is that of Mr. Lowitz. He mixes three parts of the acetite of copper with eight parts of a ſulphat of potaſh ſurcharged with acid, (prepared by diſtilling ſulphuric acid from potaſh, to dryneſs). This mixture, in dry powder, contains as much redundant ſulphuric acid as is ſufficient for ſaturating the copper or its oxyd, and for extricating the whole of the acetous acid, with a very moderate heat. He affirms that in this way we obtain it, with all the fragrance poſſible, from this preparation.

Nitric, or the oxygenated muriatic acid, or aqua regia, might be employed, with proper precautions, to decompound the cupreous acetite, and ſeem the fitteſt for enabling us to judge whether the acetous acid can be ſuperoxygenated.

[*Note* 30. *p.* 665.]

I muſt not omit this opportunity of making ſome remarks on this mode of concretion of the ſilver. It muſt happen in conſequence of an attraction which brings together, in

a certain determinate manner, the minute atoms into which the ſilver is divided. The ſame thing is obſervable in numberleſs inſtances of precipitation, and is probably univerſal. Often, indeed, the precipitate is a fine impalpable powder; but each particle of this is a mountain, in compariſon of the atoms in their ſtate of ſeparation, while chemically united with thoſe of the ſolvent. Often are we able to ſee with a microſcope, that each of theſe particles of powder is a group of minute regular forms or cryſtals. Nay, even when the precipitate is gelatinous, as in luna cornea, I am perſuaded that its ſtructure is not uniform, but plated or ſymmetrical. This I conclude, from obſerving that the formation of ſuch jellies proceeds in a way which reſembles the more ſenſible cryſtallizations. When a ſolution is juſt ready to ſhoot into cryſtals, if we touch it with a particle of the cryſtal, the change begins there, and ſpreads from it as a centre. I obſerve the ſame thing in the formation of ſome gelatinous concretions by inſpiſſation. But, to return to this precipitation of ſilver;—it is particularly to be remarked, that, although the concretion proceeds from a baſis ſending out ſtems, from which proceed branches, which again produce ſubordinate ramifications, and the concretion has therefore been called a vegetation, it does not at all proceed in the manner of a growth, or a gradual protruſion from a parent trunk. This trunk does not grow or change at the ſame time. Nor does it appear to contribute any thing whatever to the increaſe or ramification. It remains of the ſame length, the ſame diſtance remains between every branch, and all the increment is plainly an accretion of external matter applied to its extremities, or to different parts of its ſurface in ſucceſſion. The additions are of matter previouſly floating about. The little ſhrub, therefore, is not produced by the gradual developement of a ſeminal body, nor by the action of its organical ſtructure on the fluid matter which it pumps along its canals, aſſimilating it as it goes along, and ſecreting or rejecting it according to fixed laws. In the preſent caſe, every atom ſeems to have the ſame powers, and to be equally capable of becoming either the ſtem or any one of the branches. When we obſerve the gradual formation with attention, aſſiſted by a microſcope, we obſerve each little addition to ſtart into exiſtence in a moment; and we can ſcarcely tell when or where to expect the next. They are all *accretions*,—*appoſitions*, of ſilver previouſly floating about in the ſolution. Sometimes, indeed, a little branch employs a ſenſible moment in attaining its full length; but even then, I preſume, that this is a ſucceſſion of many inſtantaneouſly formed plates; for we know that *all* cryſtals are of a tranſverſely plated ſtructure. I cannot but think that the atoms of ſilver continue to be ſuſpended, or to float about for ſome little time, after their ſeparation from the acid, in their individual and inviſible form; and that they are thus carried to ſome diſtance from the copper (*in contact of which only* they are detached from the acid) before they arrange themſelves in ſome little ſymmetrical group, fitted to form a new cryſtal, obſerving ſuch a law of attraction, that it muſt attach to thoſe already formed, in one way, but not in another. Or, ſhall we ſay that there is a power reſembling magnetiſm, electricity, or galvaniſm, propagated from the central bit of copper? This laſt (galvaniſm) ſeems to offer the beſt means for *illuſtrating* the phe-

nomenon; for it cannot be called an explanation, but it is of the ſame kind with all other explanations purely chemical. None of them aim at aſcertaining the proximate cauſe, and its manner of action. It is thought a ſufficient explanation, if we ſhew that the phenomenon is one of a great claſs already known, although we are equally in the dark with reſpect to each of them. The philoſophical chemiſt, indeed, frequently attempts ſomething more, and to ſhew *how* the chemical attractions operate in producing the phenomenon. This is preciſely the difficulty here. The queſtion is not chemical, but mechanical. We are required to ſhew how certain centripetal, or centrifugal forces ſeparate certain particles, and bring them together again in another determinate manner. The chemiſt aſcertains, from obſervation, the affinity, that is, the caſes in which ſuch ſeparations and reunions are invariably effected. When he goes further, and ſpeaks of his greater and ſmaller attractions, of one attraction oppoſing another, &c. he ſpeaks as a mechanician, and generally without any diſtinct conceptions of the ſubject. In queſtions of this kind, the object before the mind is an atom of *moveable matter*, under the influence of a *moving force*; and all diſcuſſion muſt now proceed on the acknowledged laws of motion. I take it that the preſent phenomenon is one of thoſe which ſets the inſufficiency of thoſe uſual modes of reaſoning in the cleareſt light. I cannot conceive any action between the copper and the *adjoining* acid which can produce the depoſition of a *remote* atom of ſilver from a *remote* atom of acid, which will not be produced by the action of the already formed ſolid ſilver, adjoining to that particle of acid which depoſits its ſilver. All that I can do, is to recollect that ſomething very like it happens when I bring a magnet near a parcel of iron-filings, which were lying confuſed, and without any mutual influence,—every individual rag of iron becomes in an inſtant active, turns about, and preſents one extremity to one adjoining rag of iron, and the other to another; they adhere together; and when I draw one away, it drags another after it, &c.; and all this activity is at an end whenever I remove the magnet. Here then is a conſiderable reſemblance of effect, but it is ſtill very imperfect. The mere preſence of the copper is not enough; it muſt be in the very act of diſſolving in the *contiguous* acid. The galvanic phenomena have a much cloſer reſemblance to what we are now conſidering. Indeed they are almoſt the ſame. We have at one wire an oxydation going on, and a deoxydation going on at the other, and the two have an invariable dependence on each other. The one cannot happen unleſs the other alſo happen; and we cannot tell which is the prior event. But this is only an illuſtration; and the immediate actors and powers remain as much unknown as ever. Can the phenomenon be conceived in this way? It is probable that an unſaturated ſolution of copper, and a ſaturated ſolution of ſilver in the ſame acid, may remain mixed together without changing. We know this to be true with ſaturated ſolutions of ſilver and mercury. When copper is put into ſuch a mixture, it *may be* that a greater doſe of it being acquired by the acid in contact with it, liberates ſome ſilver, (though I cannot tell how) which liberated ſilver floats off, and is carried by the fluid till

it meets with a cryſtal of ſilver already formed, acting with polar forces, like the particles of iron-filings, and there it ſettles ſymmetrically.

It is to be wiſhed that chemiſts would endeavour to acquire ſome more preciſe notions than they ſeem to content themſelves with at preſent, of thoſe internal procedures. Such unbounded uſe is made of the change of partners (ſo to expreſs myſelf) between oxygen, hydrogen, azote, and carbon, in the chemical phenomena of vegetable and animal ſubſtances, that every tyro from the chemical claſſes finds himſelf in a condition to write a ſyſtem of chemiſtry, which leaves nothing unexplained, and admits of no contradiction. The author of a *Pyrologia*, by bringing caloric into the chemical dance, finds himſelf qualified to make a world. It is time to check ſuch unprofitable ſpeculations. Dr. Black's maxim of ſetting one foot firm on ground which we know familiarly, before we attempt to make another ſtep, is the only ſafe way of proceeding in this noble but difficult ſcience. An example, ſtill more remarkable and puzzling, occurred to me very lately. I had ſet up a galvanic pile, of 240 pairs of ſilver and zinc plates, having pieces of woollen cloth ſoaked in a ſaturated ſolution of ſea ſalt. It ſtood on a table in a warm room; and the evening ſun ſhone on it. Chancing to look at it from the other ſide of the room, I obſerved a moſt beautiful nimbus or glory ſurrounding a great part of the column, exhibiting fine priſmatic colours. I went immediately to take a nearer view of it, and it vaniſhed. Returning to my chair, I ſaw it again, but not if I moved my head much to either ſide. I went to it again, and viewing it with a reading glaſs, I obſerved that each piece of cloth had, all around, fine cryſtals ſtanding out almoſt horizontally. They were more ſlender than the fineſt human hair; and many of them (no thicker than the reſt) were two inches long. They were perfectly ſtraight, except a ſmall bending by their own weight. I could perceive, by their manner of reflecting the light, that they were angular priſms, and that they were jointed tranſverſely, like the *equiſetum lacuſtre*.

Now I would aſk how theſe cryſtals of ſoda (for ſuch they are) were formed? I let ſome fibres of cotton fall on them; and could obſerve that the part *beyond* the fibre increaſed, without the fibre itſelf being carried farther from the ſoaked cloth by an increaſe of what was between them.—It is very myſterious.

[*Note* 31. *p.* 681.]

When we reflect on he manner in which it explodes, when lying looſe on a plate of metal, where it is perfectly open to expand upwards and laterally, and on the very ſmall portion of this ſmall quantity of matter that is hindered from expanding downwards, and on the impreſſion that it makes, it gives us ſome notion of the immenſe velocity with which it expands. I found that ſeven grains, lying on a plate of braſs, and exploding by heat, made as great an impreſſion as a piece of iron, two and a half pounds weight, falling on it with the velocity of 25 feet in a ſecond. We cannot compute the downward

action at more than one-fourth of the whole expanſion. We muſt therefore calculate the velocity of $1\frac{3}{4}$ grains which will give as great a blow as the piece of iron, which weighed 17,500 grains. We ſhall find this velocity to be 250,000 feet in a ſecond, which is nearly 45 miles in a ſecond. Yet this is probably very ſmall in compariſon with the velocity of expanſion of the fulminating ſilver, perhaps not the 100th part of it. Thus we approach to ſome of thoſe aſtoniſhing forces that operate in the emiſſion and refraction of light, and many other phenomena of nature.

[*Note* 32. *p.* 707.]

No obſervations, made with any immediate purpoſe of employing them in the lecture, are to be found among Dr. Black's papers, on ſeveral ſubſtances which ſeem to be pretty generally admitted as metallic; namely, thoſe called *molybdenum*, *tellurium*, *chromum*, *tungsten*, *uranium*, *titanium*, &c. It appears that he did not conſider the very imperfect knowledge acquired of them as of importance enough to occupy any of the time allotted for a courſe of elementary inſtruction in the *ſcience* of chemiſtry. The few diſtinguiſhing properties eſtabliſhed with reſpect to each of them are not ſuch as have any extenſive influence, either on doctrinal points, or the conduct of chemical proceſſes, or the improvement of the chemical arts. Some of them, particularly the one called titanium, ſeems to have engaged his attention a good deal: But the ſtate of his health precluded all labour on his part to acquire a more perfect knowledge of its properties

END OF VOLUME II.

Printed by Mundell & Son, Edinburgh.

INDEX.

A.

	PAGE.	NOTES.
Absorbent earths,	II. 20.	
Acetous acid,	I. 406.	
—— ammoniac,	474.	
Achromatic teleſcopes,	II. 614.	
Acids,	I. 382.	
Adopters,	299.	
Æther,	II. 315, 331.	
Æthiops martialis,	464.	
Affinity, or attraction, chemical,	I. 266, 278.	539 to 544.
Agate,	II. 175.	
Aggregation,	I. 280.	
Alabaſters,	II. 172.	
Alcohol,	308.	
Alkali foſſile acetatum,	I. 473.	
Alkalis,	II. 70.	
Alkaline earths,	20, 22, 70.	
—— ſalts,	I. 371.	
—— ſubſtances, affinities of,	II. 119.	
Alum,	146.	
Amalgama,	549.	
Amber,	378.	
Ambergriſe,	360.	
Amianthus,	168.	

	PAGE.	NOTES.
Ammoniacal ſalts,	I. 463.	
Annealing of metals,	139.	
Antimonial cauſtic,	II. 558, 575.	
Antimonium muriatum,	558.	
——— præparatum,	563.	
——— tartariſatum,	579.	
Antimony,	553.	
———, butter of,	558.	
———, cinnabar of,	575.	
———, regulus of,	561.	
Apparatus, chemical,	I. 286.	
Aquafortis,	403.	
Aqua-regia,	II. 677.	
Argal,	I. 476.	
Arbor Dianæ,	II. 666.	
Ardent ſpirits,	305.	
Argillaceous earths,	21, 142.	
Arſenic,	419.	
——— acid,	422.	
Arſeniats,	424.	
Aſbeſtos,	169.	
Aſſay-furnace,	I. 325.	
Aſſaying,	II. 434.	
Aſtringents, vegetable,	478.	
Athanor furnace,	I. 321.	
Atmoſphere, of the unequal temperature of the,	100.	
Atoms, elementary,	341.	
Aurum fulminans,	II. 680.	
——— muſivum,	628.	
Azotic gas,	108.	

B.

Bacon's (Lord Verulam) theory of heat,	I. 31.	
Balloons,	II. 227.	
Balſams,	354.	
Balſamum ſulphuris craſſum,	368.	
Barilla,	I. 377.	

	PAGE.	NOTES.
Bar-iron,	II. 496.	
Barytes,	134.	
Baſaltes, (ſignature Y)	163.	
Baths (chemical), various kinds of,	I. 296.	
Bay-ſalt,	460.	
Beaumé's (M.) theory of cryſtallization,	365.	
Beccher's opinion on the principle of inflammability,	233.	
——— general furnace,	331.	
Bees-wax,	II. 370.	
Benzoic acid,	359.	
Bergman's nomenclature,	I. 487.	
Bezoardicum minerale,	II. 577.	
Biſmuth,	594.	
Bittern,	55.	
Bitumens,	376.	
Black's (Dr.) definition of chemiſtry,	I. 11.	
——— furnace,	333.	
——— nomenclature,	493.	
——— claim to the diſcovery of latent heat,	I. ———	522.
——— table of mercurial preparations,	II. ———	753.
Bleaching, new proceſs of,	450.	
Blind coal,	381.	
Blow-pipe,	I. 326.	
Blue lights (Chineſe),	433.	
Blue vitriol,	II. 634.	
Boerhaave's definition of chemiſtry,	I. 8.	
——— theory of heat,	33.	
——— experiment on the cooling of bodies,	88.	
Boiled ſalt,	461.	
Boiling temperature in vacuo,	151.	
Bolognian phoſphorus,	299.	
Boracic acid,	I. 410.	
Borat of lime,	II. 133.	
Borax,	I. 410, 483.	
Boyle's invention of ſpirit-of-wine thermometers,	52.	
Braun's (Profeſſor) experiments for producing artificial cold,	72.	
Bronzes,	II. 646.	
Brownrigg's (Dr.) ſpeculations on fixed air,	93.	
Buffon's theory of the earth,	15.	

C.

	PAGE.	NOTES.
Cahoutchouc,	II. 363.	
Calamine,	592.	
Calcareous earths,	23, 121.	
——— ſpar,	24.	
Calcination of metals,	394.	
Calomelas,	536.	
Calx extincta,	36.	
Camphors,	351.	
Canton's phoſphorus,	300.	
Capacity of bodies for the matter of heat,	I. 80.	
Capillary attraction,	263.	
Carbone,	II. 99.	
Carbonated hydrogen,	284.	
Carbonic acid,	99, 287.	
———, affinities of,	118.	
Carnelian,	175.	
Caſe-hardening,	505.	
Caſt iron,	495.	
Caſtor,	361.	
Cauſtic alkali,	44, 52.	
Cavendiſh's (Mr.) experiments on nitric acid,	I. 442.	
——— fixed air,	II. 90.	
——— diſcovery of nitrogen,	107.	
Cementation, chemical,	I. 293.	
Ceruſſa,	II. 609.	
——— antimonii,	583.	
Chalcedony,	175.	
Chamelion minerale,	453.	
Charcoal,	I. 310, II. 282, 290.	
Chemical ſubſtances, arrangement of,	I. 344.	547.
Chemiſtry, introductory remarks on,	1.	
———, various definitions of,	7.	
———, general views of it as a ſcience,	12.	
Chert,	II. 157.	
Chimney, cauſes and cure of ſmoaky,	I. 319.	
Cinnabar,	II. 546.	
——— of antimony,	575.	

	PAGE.	NOTES.
Circulation, chemical,	I. 292.	
Civet,	II. 361.	
Cleghorn's (Dr.) theory of heat,	I. 33, 196.	
Clays,	II. 142.	
Coaks,	I. 311. II. 283.	
Coal, foſſil,	I. 314. II. 379.	
Cobalt,	II. 597.	
Cohobation, chemical,	I. 292.	
Colcothar,	II. 464.	
Cold,	I. 27, 70.	
Combination (chemical), theories of,	258.	
——————, rules for procuring,	270.	
Combuſtion,	227.	
Common ſalt,	450, 455.	
Compoſition, attraction of,	280.	
Congealing point of a body,	114.	
Congelation, phenomena of,	126.	
Copal,	II. 358.	
Copper,	632, 648.	
Copperas,	464.	
Corroſive ſublimate,	536.	
Cort's proceſs of manufacturing bar-iron,	496.	
Corundum,	189.	
Crawford's (Dr.) theory of inflammation,	205.	
Cream of tartar,	I. 477.	
Crocus antimonii,	II. 571.	
Crucibles, different kinds of,	I. 294.	
Crude antimony,	II. 561.	
Cryſtallization,	I. 357, 364.	
Cubic nitre,	448.	
Cucurbits,	299.	
Cullen's (Dr.) experiments on vaporization in vacuo,	I. 162.	
Cupellation of gold and ſilver,	II. 656, 675, 692.	

D.

Dampers,	I. 320.	
Decrepitation of ſalts,	363.	
Deflagration,	429.	

	PAGE.	NOTES.
Deliqueſcence,	I. 252.	
De Liſle's ſcale for thermometers,	67.	
Dephlogiſticated air,	396, 438.	
——————muriatic acid,	II. 445.	
Derham's (Dr.) opinion as to the aſcent of vapour,	I. 206.	
Deſagulier's (Dr.) ibid.	ib.	
Detonation,	429.	
Diamond,	II. 186, 293.	
Diffuſion,	I. 252.	
Digeſtion, chemical,	293.	
Digeſtive ſalt,	449.	
Diſtillation,	166, 199, 295.	
———— per aſcenſum,	298.	
————, furnace for,	329.	
Dolomieu's obſervations on quartz and precious ſtones,	II. 197.	
Dreſſing the ore,	432.	
Dulcified ſpirit of nitre,	322.	
Dyke in mining,	9.	

E.

Earths,	II. 1.	
———, various orders of,	20.	
Ebullition,	I. 152.	
Effervescence,	250.	
Efflorescence of ſalts,	360, 363.	
Elective attractions,	274.	544.
——————, double,	279.	
Electricity, as a means of producing heat,	302.	
Eliquation in metallurgy,	II. 561.	
Emetic tartar,	578.	
Empyreal air,	I. 437.	
Enamels and glazing for pottery,	II. 615.	
Eudiometer,	522.	
Evaporation,	I. 198, 295.	
————, natural,	203.	
———— produces cold,	211.	
Expanſion of bodies by heat,	36.	

F.

	PAGE.	NOTES.
Factitious gems,	II. 190.	
Fahrenheit's ſcale for thermometers,	I. 65.	
——— experiments on the congelation of water,	127.	
Feldt ſpar,	II. 166.	
Fermentation, as a means of producing heat,	I. 303.	
Finery cinder,	II. 497.	
Fire-damp,	223.	
Fixed air,	75, 86, 94.	
———, affinities of,	117.	
———, medical virtues of,	96.	
Flexible earths,	21.	
——— ſtones, (ſignature ϒ)	167.	
Flint,	157.	
—— glaſs,	614.	
Florentine academicians; their invention of ſpirit-of-wine thermometers,	I 52.	
Flores martiales,	II 428.	
—— argentei,	554.	
—— antimonii,	565.	
Fluat of lime,	125.	
Fluidity produced ſolely by heat,	I. 106, 142.	
Fluor, or fluor mineralis,	II. 125.	
Fluoric acid,	127.	
Foſſil acids,	I. 382.	
—— alkali,	375.	
Fourcroy's definition of chemiſtry,	11.	
——— theory of heat,	32.	
French nomenclature,	489.	
Frigorific particles, erroneous ſuppoſition of,	108.	
———mixtures, explanation of the effects of,	130.	
Fuel; inflammation of it, as a means of producing heat,	307, 315.	
Furnace,	317.	
——— made of crucibles,	333.	
Fuſible earths,	II. 21.	
——— ſtones,	164.	

G.

	PAGE.	NOTES
Gallic acid,	II. 479.	
Garnat,	168.	
Gems,	175.	
Geoffroy's table of elective attractions,	I. 276.	
Glaſs,	II. 159.	
——— furnace,	I. 327.	
Glauber's ſalt,	424.	
———ſpirit of nitre,	II. 319.	
Globe, great changes of the,	11.	
Gold,	652, 676.	
—— duſt,	697.	
Granite,	167, 173.	
Gravel,	156.	
Gravitation,	I. 263.	
Green vitriol,	II. 463, 489.	
Gum-reſins,	362.	
Gun-powder,	I. 432.	
Gypſum,	II. 31, 121.	

H.

Hales's (Dr.) diſcovery of fixed air,	II. 62.	
Halley's (Dr.) opinion as to the aſcent of vapours,	I. 207.	
Hard earths,	II. 21.	
Heat,	I. 22, 30.	
——, various theories of,	31.	
——, expanſion of bodies by,	36.	
——; whether it produces increaſe of weight by increaſing the bulk of a body,	I. 47.	511.
——; diſtribution of it among bodies,	76, 98.	510.
——, celerity of the communication of,	84.	503.
——, the ſole cauſe of fluidity,	106, 139, 142.	
—— (latent),	137, 172.	512, 522.
——, abſorbed in ebullition, is ſeparable by condenſation,	163.	
——; indications of it in vapour,	170.	
——, reflections on the union of bodies with,	192, 199, 242.	

	PAGE.	NOTES.
Heat, the ſole cauſe of evaporation,	I. 210.	
——, connection of light and,	217.	
——, imperfect ſeparation of compound bodies by,	254.	
——, various means of producing,	301.	
Heats (meaſurable), ſcale of,	220.	
—— (ſenſible), table of,	221.	
Helliot's ſympathetic ink,	II. 599.	
Hepar ſulphuris,	I. 395.	
Hepatic gas,	II. 273.	
Hitches in mining,	10.	
Hoffman's mineral anodyne liquor,	326.	
Homberg's phoſphorus,	296.	
Hooke's (Dr.) remarks on inflammation,	I.	535, 553.
Hope's (Dr.) analyſis of ſtrontites,	II. 137.	
Hornblende, (ſignature ϒ)	161.	
Hutchin's (Mr.) experiments for producing artificial cold,	I. 74.	
Hutton's (Dr.) obſervations on ſaline ſolutions,	353.	
——— theory of the earth,	II. 19.	
Hydrargyrus muriatus,	536.	
Hydrogenous gas,	240.	
Hydro-ſulphuret,	275.	

I.

James's powder,	II. 574.	
Jaquin's (Profeſſor) experiments on lime,	72.	
Jaſpers,	174.	
Ice, Indian proceſs for making,	I. 212.	
Iceland cryſtal,	II. 24.	
Ignition, or incandeſcence,	I. 216.	
Inflammable ſubſtances,	II. 203.	
——— air,	223.	
——— exploded with vital air,	232.	
Inflammation, cauſe of,	I. 241.	538.
Ink for writing,	II. 480.	
Iron,	457.	
——, medicinal virtues of,	506.	

	PAGE.	NOTES.
Iron mould,	II. 472.	
Iron, ores of,	491.	
Irvin's (Dr.) opinion of the capacity of bodies for heat,	I. 141.	
——— theory of heat insufficient,	194.	

K.

Kali acetatum,	I. 470.	
Kelp,	377.	
Kermes mineralis,	II. 568.	

L.

Labrador stone,	II. 173.	
Lacca,	362.	
Lakes (deep); cause why they are not frozen in winter,	I. 99.	
Lamp-black,	II. 341.	
—— furnace,	I. 321, 330.	
Lapis lazuli,	II. 173.	
—— nephriticus,	174.	
Latent heat, examples of,	I. 137.	512, 522.
——— in steam, measure of the,	172.	
———, theory of it,	175.	
Lava, (signature ϒ),	II. 162.	
Lavoisier's theory of inflammation,	I. 239.	
——— remarks on carbonic acid,	II. 100.	
——— experiments on airs,	105.	
——— theory of combustion and acidity,	212.	
——— decomposition of water,	238.	
——— theory of the calcination of metals,	403.	
Lead,	603.	
——, ores and medicinal preparations of,	620.	
Light, connection of heat and,	I. 217.	
—— of the sun; its effect on vegetables,	236.	532.
Lime-mortar,	II. 47.	
—— slaked,	36, 73, 76.	
——, theories respecting,	50.	

	PAGE.	NOTES.
Lime water,	II. 37.	
Liquefaction,	I. 116.	
Liquor fumans Libavii,	II. 627.	
Litharge,	606.	
Lithophyta,	26.	
Lixivium ſanguinis,	474.	
Lodes,	9.	
Loriot's (M.) preparation of mortar,	49.	
Lowitz's experiments with frigorific mixtures,	I. 136.	
Luna cornea,	II. 663.	
Lunar cauſtic,	661.	
Lutes,	I. 335.	

M.

Macbride's (Dr.) ſpeculations on fixed air,	II. 89.	
Macquer's definition of chemiſtry,	I. 7.	
——— theory of heat,	32.	
——— lime,	II. 51.	
Magneſia alba,	54, 67.	
Magneſium,	437.	
Manganeſe,	473.	
Marbles,	171.	
Margraaf's experiments on lime,	72.	
Marle,	26.	
Martial pyrites,	488.	
Martin's (Dr.) experiments on the capacities of bodies for heat,	I. 81.	
Mayhow's (Dr.) experiments on nitre,	428.	
Melting point of a body,	114.	
Menſtruum,	252.	
Mercury employed in thermometers,	52.	
———, qualities of,	II. 510, 551.	
Metallic ſubſtances,	389.	
———; their ſolution in acids,	406.	
——— relation to the ſalts,	410.	
——— earths, and inflammables,	412.	

PAGE. NOTES

Metallurgy, - - - II. 431.
Mica, - - (ſignature *r*), - - 168.
Mineral acids, - - - I. 382.
——— waters, - - - II. 718.
Mines, of the ventilation of, - - I. 94.
Minium, - - - II. 606.
Mirrors, foiling of, - - - 550.
Mixture (frigorific), - - I. 130.
———, general effects of, - - 248, 257.
———, as a means of producing heat, - 303.
Mocoe, - - - II. 176.
Moon; cauſe of her faint light, - - I. 218.
Mountain cork, - - - II. 169.
Muffle of a furnace, - - - I. 325.
Muriat of ſilver, - - - II. 662.
Muriatic acid, - - I. 399, 403.
————, proceſs for obtaining, - 452.
——— æther, - - - II. 327.
Muſchenbroeck's erroneous opinion as to the freezing of water, - - - I. 108.
Muſk, - - - - II. 361.

N.

Newcomen's ſteam-engine, - - I. 182.
Nickel, - - - II. 601.
Nitre, - - - - I. 425.
——, natural hiſtory of, - - 444.
——, mother lee of, - - II. 54.
Nitrate of ſilver, - - - 660.
Nitric acid, - - - I. 401, 440.
—— æther, - - - II. 323.
Nitrous acid, - - - I. 399, 402, 434.
——— ammoniac, - - 467.
——— gas, - - II. 521, 527.
——— oxyd, - - - 529, 746.

O.

	PAGE.	NOTES.
Ochre,	II. 472.	
Oils uſed as fuels,	I. 309.	
——, nature of,	II. 340.	
——, aromatic,	345.	
——, drying,	369.	
——, empyrumatic,	372.	
Oils, eſſential,	345.	
——, expreſſed,	364.	
——, unctuous,	ibid.	
Onyx,	176.	
Opal,	ibid.	
Oxyd,	403.	
—— of azote,	529.	
Oxygen gas,	I. 439.	
Oxygenated muriatic acid,	II. 446.	
Oxy-muriatic acid,	ibid.	
Oxy-muriats,	448.	
———— of tin,	626.	

P.

Papin's digeſter,	I. 149.	
Paſtes,	II. 190.	
Pearl white,	595.	
Peat,	——	736.
Pellucid gems,	176.	
Petrifying waters,	24, 95.	
Petroleum,	376.	
Phlogiſticated air,	I. 396. II. 106.	
Phlogiſton,	I. 231, 391.	
Phoſphat of lime,	II. 131.	
Phoſphoric acid,	131, 253.	
Phoſphorus,	250, 265.	
Pinchbeck,	646.	
Pitch,	375.	

	PAGE. NOTES.
Plants, ſimilarity of the acids of,	II. 339.
Plaſtic earths,	21, 142.
Platina,	699.
Plumbago,	462.
Pneumatic chemiſtry,	102.
Porcelain,	191.
Porphyry,	168, 172.
Potaſh,	I. 372.
Precious ſtones,	II. 170.
Precipitation,	I. 256.
Preſſure, effect of it on bodies in changing their ſtates,	148.
Prieſtley's diſcovery of phlogiſticated air,	396, 438.
——— experiments on airs,	II. 103.
——— eudiometer,	522.
——— diſcovery of oxygen,	540.
Pruſſian alkali,	474, 741.
——— blue,	474.
Pruſſiat of potaſh,	740.
Pruſſic acid,	ibid.
Puddingſtone,	157, 173.
Pulſe glaſs,	I. 179.
Pulvis fulminans,	433.
——— algarothi,	II. 558, 576.
Pumice ſtone, (ſignature ϒ),	162.
Purple of Caſſius,	686.
Puzzolane, (ſignature ϒ),	166.
Pyrophori,	287, 296.

Q.

Quartz,	II. 163, 197.
Quick-lime,	34, 52, 110.

R.

Reaumur's ſcale for thermometers,	I. 67.
——— porcelain,	II. 161.

	PAGE.	NOTES.
Red precipitate,	II. 532.	
Reduction of metals,	398, 433.	
Refining,	434.	
Refrigeratory,	I. 298.	
Regenerated tartar,	470.	
Regulus of a metal,	II. 399.	
——— antimonii,	582.	
Refins,	354.	
Retorts,	I. 299.	
Reverberatory,	326.	
Robifon's (Profeffor) experiments on the effect of light in vegetation,	236.	532.
——— remarks on Lavoifier's theory of acidity and combuftion,	II. 215.	
——— the divellent affinities of metals,	——	751.
Roafting an ore,	433.	
Rocks; their degradation by the weather,	7.	

S.

Saccharum faturni,	II. 610.
Sal ammoniac,	I. 468.
— catharticus amarus,	II. 55.
— diureticus,	I. 470.
— martis,	II. 463.
— microcofmicum,	131.
— vegito-minerale,	I. 473.
Saline folutions,	350.
Saltpetre,	425.
Salts,	347, 352.
——, compound or neutral,	414.
———, table of,	420.
——, fynonimes of,	486.
Sanctorio's invention of air thermometers,	50.
Sand-ftone,	II. 156.
Saturation,	I. 253.
Sauffure's eudiometer,	II. 524.

	PAGE.	NOTES.
Scheele's diſcovery of phlogiſticated air, -	I. 396, 438.	
——— fire-air, or empyreal air, -	437.	
——— experiments on airs, -	II. 105.	
——— diſcovery of the fluoric acid, -	127.	
——— theory of fire, heat, and light, -	206.	
Schoerl, - (ſignature ϒ), - -	161.	
Seas; cauſe why they are not frozen in winter, -	I. 99.	
Sea-ſalt, - - -	462.	
——water, - - -	II. 714.	
Sebacic acid, - - -	343.	
Sedative ſalt, - - -	I. 410.	
Selenites, - - -	II. 31.	
Semipellucid gems - - -	175.	
Serpentines, - - -	172.	
Shells, - - -	25.	
Silica, - - -	153.	
Siliceous earths, - - -	21, 153.	
——— petrifactions and cryſtals, - -	158.	
——— of wood, - -	174.	
Silver, - - - -	652, 658.	
——, ores of, - - -	671.	
Smalt, - - -	600.	
Soap, - - - -	366.	
Soda, - - - -	I. 377.	
—— phoſphorata, - - -	II. 263.	
—— vitriolata, - - -	I. 424.	
Solution, - - -	252.	
Soot, - - -	II. 341.	
Spars, - - -	24, 173.	
Spelter, - - - -	583.	
Spermaceti, - - -	369.	
Spirit of wine, - - -	305.	
——— employed to produce heat, -	I. 308.	
Spiritus Mindereri - - -	474.	
Stahl's opinion on the principle of inflammability, -	233.	
——— theory of phlogiſton, - -	390.	
——— lime, - -	II. 51.	

	PAGE.	NOTES.
Stahl's theory of the calcination of metals, -	II. 400.	
Stalactites, - - - - - - -	24.	
Stannum, - - - - - - -	622.	
Steam cookery, - - -	I. 180.	
—— engines, - - - -	181.	
Steel, - - - - - -	II. 501.	
Strontites, - - - -	137.	
Suber montanum, - -	169.	
Sublimation, - - -	I. 199, 295.	
Subliming veſſels, - - -	300.	
Sugar, - - -	II. 334.	
——, acid of, - - -	336.	
Sulphat of potaſh, - - -	I. 422.	
————ſoda, - - -	424.	
————lime, - -	II. 31, 121.	
————mercury, - -	518.	
Sulphur, - - -	I. 394.	II. 269.
———, flowers of, - -	II. 272.	
———, natural hiſtory of, - -	277.	
———, balſams of, - - -	280.	
——— antimonii præcipitatum, - -	567.	
Sulphurets, - - -	272.	
——— of lime, - - -	42.	
Sulphuric acid, - -	I. 386.	II. 280.
——— æther, - - -	II. 315.	
Sulphurous acid, - -	I. 397.	II. 280.
Sun's rays, as a means of producing heat, -	I. 305.	
Sympathetic inks, - -	II. 596, 599.	

T.

Talc, - (ſignature Y), - -	II. 168.	
Tar, - - - -	375.	
Tartar, - - -	I. 475.	
Tartarous acid, - -	408, 479.	
Tartarus ſolubilis, - - -	476.	

PAGE. NOTES.

Taylor's (Dr.) experiments as to the expanſion of fluids by heat, - - - - I. 57.
Terra foliata tartari, - - 472.
—— ponderoſa, - - - II. 134.
Thermometer, - - - I. 50.
————s, imperfections of, - - 57.
————-, various ſcales for, - - 65.
————-, extenſion of our ideas of heat by means of, 68.

V.

Vaporization, reaſons for believing it univerſal, - I. 200.
Vapour and vaporization, general phenomena of, - 144.
——— dangerous from burning fuel, - - 313.
———s, opinions concerning the aſcent of, - 206.
Vegetable alkali, - - - - 372.
——— acids, - - - - 405.
———— ammoniac, - - - - - 474.
Vegetation of ſalts, - - - - 360.
Verdigriſe, - - - - II. 638.
Vermilion, - - - - - 546.
Veſſels, chemical, - - - - I. 288.
Vital air, - - - - 438, II. 105.
Vitrification of earthy bodies, - - - I. 115.
Vitriolated tartar, - - - - 422.
Vitriolic acid, - - - - - 386.
———— ; its action on inflammables, - - 389.
——— ammoniac, - - - 464.
Vitrum antimonii, - - - II. 565.
Volatile alkali (pungent), - - - 40, 245.
Volcanoes, - - - - - 490.

W.

Walker's (Mr.) experiments with frigorific mixtures, - I. 135.
Water ; expanſion of it in congelation, - - 14. 501.
———, boiling in vacuo, - - - 161.

	PAGE.	NOTES.
Water, compoſition of,	II. 235.	
———s, of natural,	708.	
Water-bath, cauſe of the equality of heat from a,	I. 98.	
——— blaſt,	324.	
Watt's (Mr.) ſteam engine,	184.	
——— experiments on diſtillation in vacuo,	190.	
Wedgewood's thermometer,	223.	
Whinſtone,	II. 157.	
White lead,	609.	
Wilſon's (Prof.) experiments on evaporation,	I. 215.	
Wind-furnace,	322.	
Wine-ſtone,	476.	
Wood as fuel,	314.	
Worceſter's (M. of) ſteam engine,	181.	

Z.

Zaffre,	II. 598.	
Zeolite, (ſignature Υ),	161.	
Zinc,	583.	
Zoophyta,	26.	

Fig. 1.
p. 40

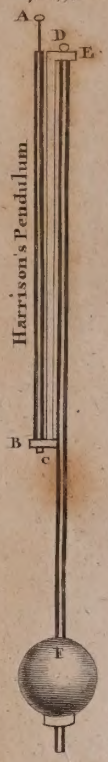
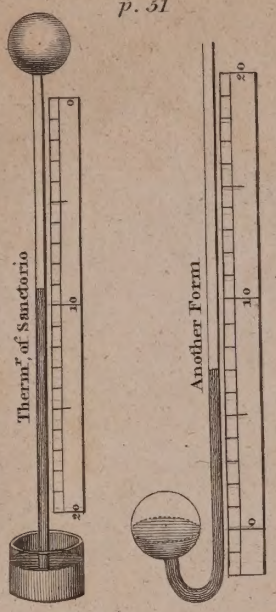


Fig. 2.
p. 51



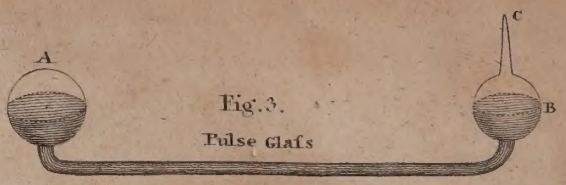


Fig. 3.

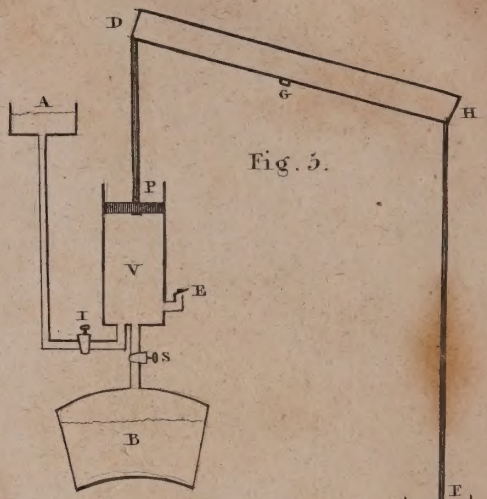


Fig. 5.

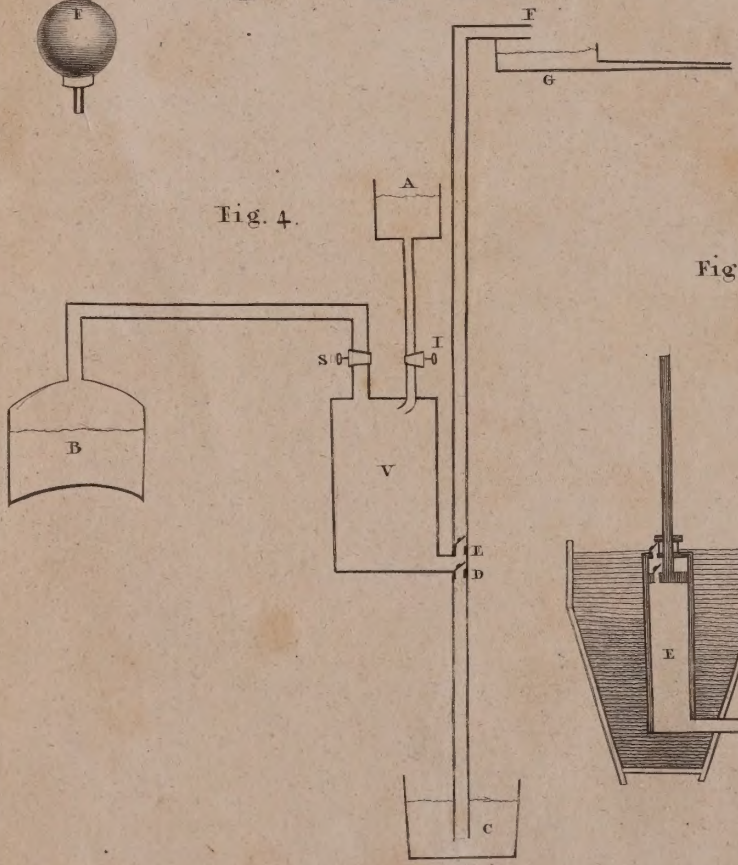
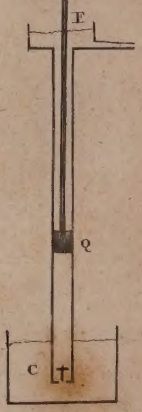


Fig. 4.



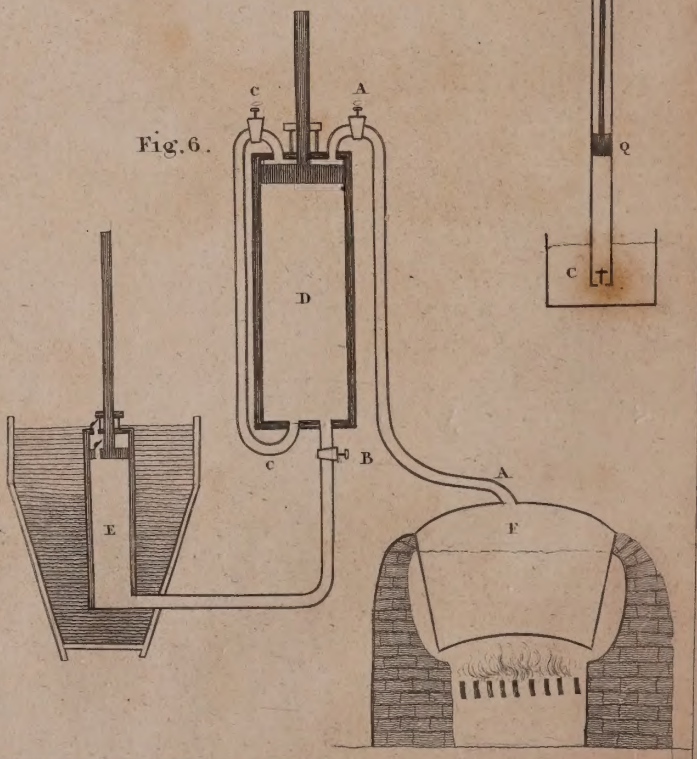


Fig. 6.

A
B
B
C
f
F
E
B
G
l
m
L
I
i
i
O
M
P
a
h
H
N

EXPLANATION OF THE PLATES.

A few figures being added to thoſe expreſsly alluded to in the Lectures, the following ſhort explanation of them was thought neceſſary.

PLATE II.

Fig. A repreſents a ſolution glaſs; the long taper ſhape of which permits agitation of the mixture, without riſk of ſpilling; it alſo prevents the loſs of ſmall drops which are ſometimes thrown out by effervеſcence, which would in ſome nice caſes of aſſay, &c. derange the calculations.

B, with the veſſel B below it, is the old circulating apparatus. The ends of the ſpouts, which come from each ſide of the capital B, are inſerted and luted into the two ſhort tubes projecting from the body or cucurbit B.

C is the Heſſian, and D the Ipſian or black-lead crucible.

E is the ordinary form of a retort, of glaſs, or earthen ware.

F repreſents a tubulated, or ſtoppered retort, with its ſtopper *f*.

G is a ſeparatory, for pouring off the clear part of a ſolution or mixture, which has any feculent matter floating above.

Fig. H repreſents a cucurbit, with its capital *h*. Its form is very nearly that of the common ſtill. To promote the condenſation, the capital ſhould be of a conſiderable diameter. Obſerve that the outer rim of the capital ſhould be lower than the hole h in the middle or throat; otherwiſe, the vapour which condenſes on the roof, and trickles down its inſide ſlope, would fall back again into the body H. But, the rim being lower, the condenſed fluid collects there, and from thence goes into the ſpout, and runs down into the receiver. The form of a capital is not unlike a muſhroom. Obſerve alſo, that the throat of the capital ſhould go into the neck of the body, and not encompaſs it. If the neck fits into the throat, the condenſed fluid lies on the luting of the joint, and is contaminated by it.

I is the moſt approved ſhape of a receiver. A taper ſpout *i* is ſometimes joined to the remote end, to be inſerted into the neck of another receiver, when the ſurface of one is not deemed ſufficient for a ſpeedy condenſation. The ſpout is ſometimes joined laterally, as at *i*; by which the fluid obtained by condenſation runs off into another veſſel, which may be ſpeedily changed, when any change of product is expected.

L repreſents one of the intermediate veſſels of Woulfe's diſtilling apparatus. The tube l reaches nearly to the bottom; the other tube m opens into the ſpace above the water in this veſſel, while its other extremity dips almoſt to the bottom of the next veſſel, &c.

M is a ſketch of the eſſential parts of which is called the *pneumatic apparatus*. The tube a, being properly bent, introduces the gas into the water or mercury which filled the jar M inverted into water or mercury. The gas riſes up through the fluid, and occupies the upper part b, the fluid ſubſiding a little on the entrance of every bubble of gas. Its elaſticity does not balance the preſſure of the atmoſphere, till the ſurface of the fluid within the jar is on the ſame level with the ſurface in the ciſtern c.

N is a perſpective view of a muffle. The projections over each of the lateral apertures are for preventing the coals with which it is ſurrounded from tumbling into the muffle as the fuel ſubſides.

O is the ſection of a cupel made of bone-aſhes.

Fig. P repreſents a ſafety-pipe, for diſtillations in which the vapours frequently change their elaſticity, and are ſometimes reabſorbed by the matter in the retort. One end is ground like a ſtopper, and fits a hole in the top of the retort, or other convenient part of the apparatus. When the vapours tend to burſt the veſſels, they preſs on the ſurface a of the fluid contained in the ball, and cauſe it to riſe through the upright tube into the cup at the top,—thus acting againſt its weight. Should the elaſticity ſtill increaſe, the gas eſcapes, by riſing in bubbles through the fluid. That this may always happen, it is neceſſary that the capacity of the cup be ſufficient to hold all the liquor which, at the beginning, filled about one-half of the ball below. Then all riſk of burſting the veſſels is avoided, and yet a continual waſte of vapour by the vent hole commonly uſed is not incurred.

On the other hand, when a reabſorption commences in the retort, which would ſometimes bring back cold matter from the receiver, and inſtantly ſplit the retort, the atmoſphere will preſs on the fluid in the vertical pipe, and riſe in bubbles into the ball, from which it will paſs into the veſſels, without riſk, except in caſes where vapours are produced which will take fire when mixed with air.

EXPLANATION OF THE PLATES.

PLATE III.

The only figure in this plate that is not explained in the courſe of lectures is fig. A, No. 1. No. 2. No. 3.

They are ſections of an experimental furnace by Mr. Macquer, which is in great eſtimation at Paris. It is made of pottery, or earthen ware, ſet on a baſe of brick-work.

No. 1. is a longitudinal ſection along the middle of its breadth. A is the aſh pit, B the ribs of the grate, C the fire place, D its door, made to lift off, and muſt be very well fitted. E is the throat of the furnace, through which the flame ruſhes into the laboratory F, where the arched roof riſes conſiderably. In its higheſt part there is a door at the ſide, repreſented by the dotted line. The materials to be ſcorified, or otherwiſe treated in this reverberatory, are put in by this door, and the ſtate of the proceſs may be ſeen from time to time. There is a ſmaller aperture on the oppoſite ſide, even with the floor, or but a very little higher. The ſcoriæ are driven into this paſſage by the bellows, in certain proceſſes. The arch of the reverberatory is much lower at G, where it communicates with the upright vent or chimney H.

No. 2. is a plan, or rather a horizontal ſection.

No. 3. is a croſs ſection. F is the fire place, and G is the arch of the reverberatory.

The numbers on various parts of theſe three figures are the dimenſions, at thoſe places, in inches.

PLATE III.

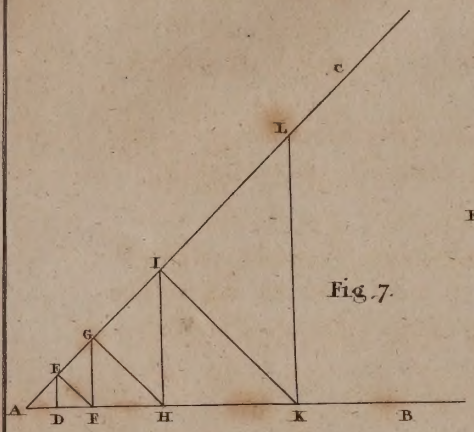


Fig. 7.

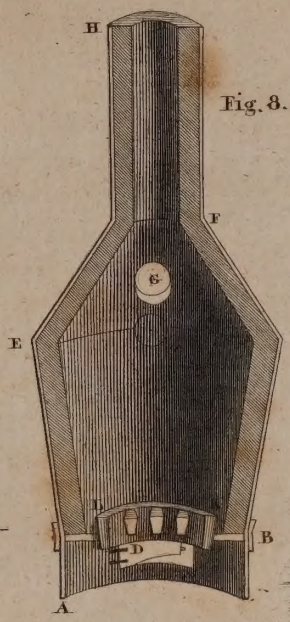


Fig. 8.

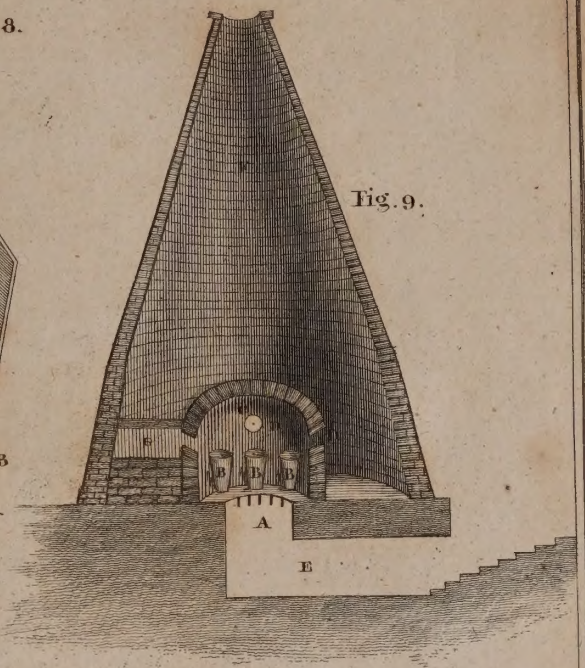
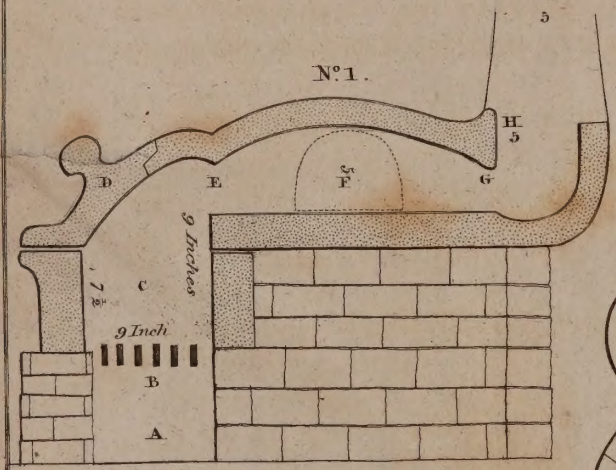


Fig. 9.



N°. 1.

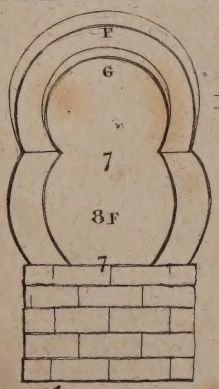
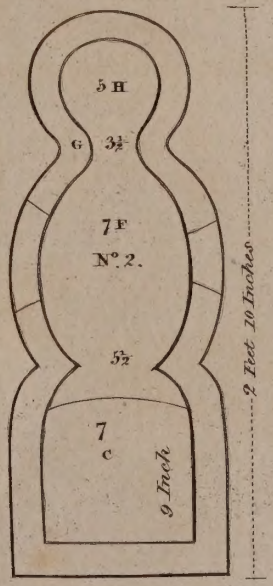


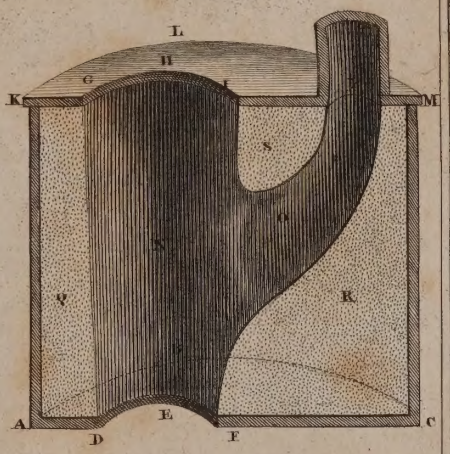
Fig. A.

N°. 3.



N°. 2.

Fig. 10.



D. Lizars sculpt.